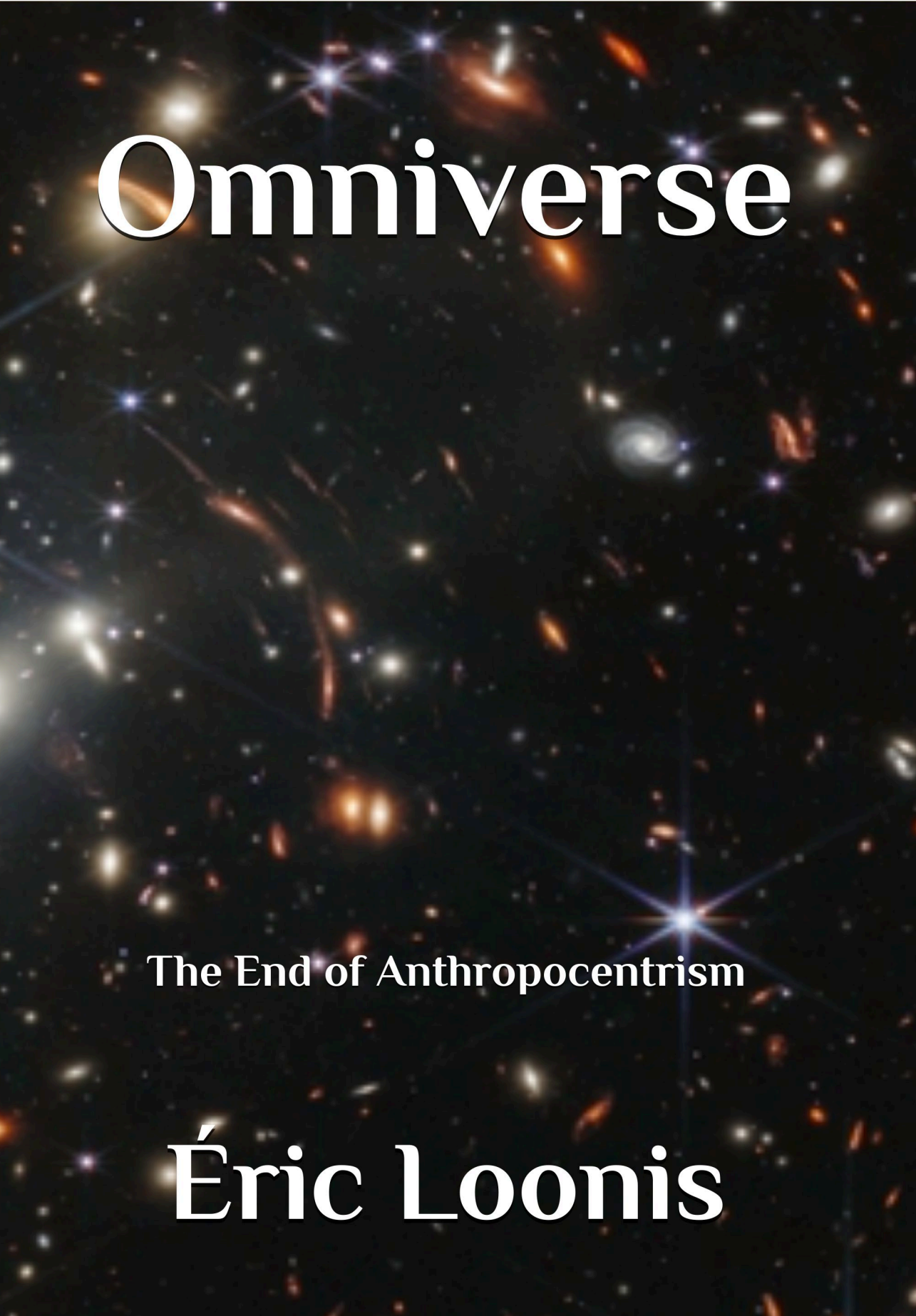
Omniverse
The End of Anthropocentrism
Éric Loonis

# Omniverse

# Omniverse

*The End of Anthropocentrism*

ÉRIC LOONIS

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**Other books of the author**

*"Infinity is not only the most powerful instrument of mathematical research, it is also the very reason for the existence of science."*

Hippolyte Margerin

*"For us convinced physicists, the distinction between past, present, and future is only an illusion, however tenacious it may be."*

Albert Einstein

*"Since the dawn of time, when our ancestors first set foot on solid ground, we have constantly wondered what reality ultimately is, raising deep existential questions. Where do all things come from? How will it all end? How large is the cosmos?"*

Max Tegmark

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# Prologue

This book is about universes. They are plural, because I will present them according to different conceptions, historical periods, and the progress of science. Beyond that, I will attempt to define what an "omniverse" might be, a "Grand Tout"[1]. I understand the omniverse as an attempt to define a totality that is at once spatial, temporal, but also modal[2], in the metaphysical sense of the term, within the framework of the ongoing dialogue between professional philosophers and physicists.

Throughout this book I will attempt to answer many fundamental questions: How was the universe first interpreted before it could be measured? What are the various conceptions of the universe in terms of size and geometry? Is there only one universe? Can we envision a multiverse? Multiverses? An omniverse? How can entropy explain consciousness and free will, and define a universe of illusions? How does a model of an omniversal fractal call into question the centrality of the human being, and even its very existence?

The first part of the book, *The Interpreted Sky*, explores the great human cosmologies before the advent of modern science. It begins with the perceptual and symbolic cosmologies of the peoples of the world, in which the sky is not an object of study but a lived space, interpreted and inhabited by narratives, forces, and relationships between humans, nature, and invisible powers. The second section examines the gradual emergence of theological and philosophical cosmologies in which the cosmos becomes a rational and hierarchical order. A relational vision of the universe then takes shape, in which the structure of the heavens is articulated with metaphysical, theological, or mathematical principles.

The second part, *The Measured Sky*, traces the moment when the sky becomes an object of measurement and systematic observation. Humanity thus moves from a symbolic cosmos to a progressively

[1] The Omniverse as the totality of reality.

[2] Lewis, 2007 (all references refer to the bibliography).

quantified universe. The first stage corresponds to the sidereal universe of the Milky Way, as it revealed itself to the astronomers of the eighteenth and nineteenth centuries. The second stage emerges at the beginning of the twentieth century with the advent of extragalactic astronomy. Thanks to the Hooker telescope and the observations of Edwin Hubble, the spiral nebulae are revealed to be independent galaxies, and the universe suddenly deepens into a space populated by hundreds of billions of galaxies, while the idea of an expanding universe is introduced. Finally, the third stage describes contemporary cosmology, shaped by the great ground-based and space telescopes, by the exploration of the entire electromagnetic spectrum, and by instruments capable of probing the deep structures of space-time. The universe then appears as a dynamic, statistical, and large-scale structured ensemble in which matter, radiation, and cosmic geometry intertwine.

The third part, *Geometries and Sizes of the Universe*, examines the global structure of the cosmos as described by general relativity and modern cosmology. It opens with the question of the geometry of the universe: the models derived from Einstein's equations and Friedmann's solutions make it possible to conceive universes with positive, zero, or negative curvature. Contemporary observations, however, suggest that our observable universe is very close to a flat geometry, within the framework of the Big Bang model and its cosmic evolution. The second section then turns to the question of the size of the universe. It examines what it means to measure a universe of which only a portion is accessible to observation, and distinguishes the observable universe from the total universe described by cosmological models. This reflection leads us to confront the limits of observation with those of theory, and to question the true extent of the cosmos.

The fourth part, *The Multiverses*, marks a decisive expansion of cosmological reflection. The question of the universe shifts toward the possibility that it may be only one element within a larger ensemble. The first section introduces the notion of the block universe arising from relativity, in which space and time form a four-dimensional structure where events are inscribed as worldlines. This representation leads to a confrontation between two philosophical conceptions of time, presentism and eternalism, and to an examination of the ontological implications of a universe

in which past, present, and future coexist within the geometry of space-time. Within this deterministic framework, the figure of Laplace's demoness makes it possible to explore this block universe concretely in order to understand its principles. The second section broadens the perspective further by examining the different types of multiverses proposed by contemporary cosmology. Starting from the distinction between repetition of the same[3] and multiplication of the possible[4], it presents a broad typology of multiverses: mathematical; global inflationary; spatial; and quantum modal[5]. This part shows how modern cosmology comes to consider that our universe may be only one among a plurality of possible worlds.

The fifth part, *The Omniverse*, introduces the central hypothesis of the book by taking a further step beyond the multiverses. It begins by drawing a connection between fractal structures and the inflationary models of contemporary cosmology. The idea of eternal inflation, which already leads to the potentially unlimited production of universes, is then related to the logic of fractals. From this connection emerges a new way of thinking about the cosmic whole: no longer as a simple collection of separate universes, but as a hierarchical and dynamic organization in which universes unfold according to a fractal structure. The second section develops this hypothesis by presenting the omniversal fractal itself. The transition from a hierarchical vision of the cosmos to a fractal organization makes it possible to conceive a whole in which universes and multiverses multiply, branch out, and interlock according to structural regularities. The fractal then becomes a model for representing the entire cosmological landscape. The hypothesis of contiguous universes finally completes this construction by proposing to explain dark matter and dark energy through possible influences between universes within this global structure. The Omniverse thus appears as the ultimate horizon of the cosmological reflection developed in this book: a fractal architecture of the whole set of multiverses.

The sixth part, *From Entropy to Consciousness*, turns to the emergence of consciousness itself. It begins by questioning the place

[3] Blanqui, 2012.

[4] Lewis, 2007.

[5] Adaptée de Tegmark, 2014.

of biology in this process and the difficulty of locating consciousness within the organization of living systems. The second section then examines the link between consciousness and entropy. Drawing on statistical physics and on contemporary reflections on time and irreversibility, it explores the idea that our experience of the world depends closely on the entropic gradient of the universe. Through the figures of Laplace's demoness and the philosophical zombie, this section highlights the deeply paradoxical character of consciousness: a phenomenon rooted in physical processes, yet carrying an illusion of autonomy. The final section deepens this perspective by examining a series of illusions constitutive of our experience of reality. The whole of these illusions, cerebral and relativistic, leads to a radical questioning of the idea that consciousness would provide direct access to reality. This part thus shows how human subjective experience is embedded in a physical universe governed by entropy and how, from this framework, what may be called the myth of consciousness is constructed.

The seventh and final part, *The End of Anthropocentrism*, draws the philosophical consequences of the cosmological journey developed throughout the book. After progressively expanding our understanding of the cosmos, the question now arises of the true place of the human being within this whole. The first section examines the anthropic illusion, that is, the persistent tendency to consider that the universe might, in one way or another, be destined for human beings. This interpretation is confronted with contemporary cosmological frameworks showing that human existence constitutes neither a goal nor a necessity in the history of the cosmos. The second section then explores the figure of the decentered human. Humanity appears as a local configuration of organized matter, arising in a particular region of the universe and at an extremely late moment in its evolution. The idea of a human centrality dissolves in the cosmic immensity, and consciousness itself becomes a contingent phenomenon embedded in the physical structures of the universe. The third section radicalizes this perspective by arriving at the idea that, within this purposeless whole, the human being is indeed without meaning. The final section offers a concluding meditation around the metaphor of an open window onto infinity. In contemplating the cosmic landscape revealed by contemporary cosmology, humanity discovers a

paradoxical situation, the oxymoron of an infinite claustrophobia. The omniversal fractal constitutes the whole within which we are enclosed, with no possible outside, yet this whole itself unfolds without limit. Within this cosmic horizon without center or purpose, the place of the human being is revealed with radical clarity as nothingness.

## WHERE DO THIS BOOK AND ITS AUTHOR COME FROM

I was pleasantly surprised to discover, in the course of my studious readings intended to document and prepare this book, that a modest architect had produced an "Anti-Dictionary of Physics."[6] It is true that physics and cosmology have always been marked by philosophy and intellectual passion, so that one does not need to be particularly strong in equations to devote oneself to them. Of course, if one wishes to be a serious author, years of reading and reflection are necessary to build one's expertise. One then becomes one of those enlightened amateurs who sometimes cross paths with the true professionals of science.

As for me, I am neither a physicist nor an astronomer, nor even particularly strong in equations, but a clinical psychologist, holding a doctorate in psychopathology, which means that I too have learned the scientific method, allowing me to distinguish between fanciful speculation and the genuine discourse of science. Thus, this entire book, devoted to the Omniverse, will be permeated by science.

At the risk of a cliché, my interest in cosmology goes back to childhood. I must have been nine or ten when my parents were summoned to the charming little school "run by the nuns" where I was finishing my primary education. The reason? A composition, on a "free topic," of which I was the intrepid author. Starting from the fascination already stirred in me by the competition between the Russians and the Americans for Earth orbit—not to mention *Tintin and Snowy on the Moon*—I had developed in my essay the original story of an astronaut who launches himself aboard a rocket, lands on the Moon, then on Mars, then reaches the stars, goes far beyond, already toward infinity, arrives in Paradise, meets a few angels but not God, because He was too busy, and then returns to Earth to tell his story to journalists. This was enough to impress those dear nuns

[6] Vegro, 2016.

who were giving me catechism lessons. There I was with my parents, who explained that "it all comes from him," that "he invented everything," and that "we, you know… we believe a little, but not that much!" The matter went no further as far as the school was concerned. But my interest in cosmology continued.

During my adolescence, my family lived in isolation on the edge of a forest, kilometers from the nearest village. A modest environment, with a stay-at-home mother and a father who was a forest ranger. The family library was striking in its frugality: twenty volumes of a 1950s encyclopedia, a Reader's Digest selection, a yellowed directory, a communicant's missal, a double-testament Bible, photo albums and… a Petit Larousse! It was an illustrated dictionary with which I tried to compensate for my cultural deprivation, reading it systematically from A to Z, alternating each day between the sections of common nouns and proper names, not forgetting the Latin expressions on the famous pink pages! Inside the covers I noted rare words (eponym, oxymoron, mithridatize…), which I learned, and others that I invented (proctosome, orchidoclast…), exercising my sense of etymology, and there I also fell in love with the portrait of Madame Rimsky-Korsakov.

Having only myself as an intellectual interlocutor, during my almost daily walks I filled my many woodland meditations with reflections on the meaning of life, the universe, its origin and its destiny. For me this was an existential imperative, especially since I had begun to understand, though still confusedly, the futility of human relationships.

It was also around that time that an uncle began giving me, once a year, the twelve issues of the magazine *Science & Vie* from the previous year. I would then spend wonderful weeks devouring them, not missing a single article about the cosmos, the stars, or plans for space travel, while gently initiating myself into the sciences. It was therefore a self-taught scientific education, which I continued to enrich throughout my adult life. So, in a few words, that is where this book and its author come from. A book that I wanted… bigger than the universe!

Part One

# THE INTERPRETED SKY

# 1. Perceptual and Symbolic Cosmologies

In the absence of written records, we will never know for certain. Yet common sense itself suggests that prehistoric humans must almost certainly have lifted their gaze toward the stars. An impressive and fascinating spectacle, which they began to observe and, perhaps already, to interpret.

From the oldest myths to the most recent cosmological models, humanity has never ceased to question what surrounds it, not only to understand the world, but to situate its own existence within it. Each era, each culture, each science has projected into the sky its own way of relating to reality.

Modern science continues this quest, but transforms it further. Einstein makes space-time a flexible fabric in which gravity is no longer a force, but geometry. The universe ceases to be stable: it expands, evolves, ages. The Big Bang replaces Creation. Quantum mechanics reveals a world of superpositions, uncertainties, and multiple states, opening the door to the idea of multiverses. Today, inflationary models of the genesis of universes, theories of quantum gravity, and hypotheses about dark matter and dark energy extend this reversal: reality is no longer a single model interpreted and as if imposed by humans, but a plural model, observed and calculated.

Ancient and medieval philosophies shifted the world from speech to concept. In Greece, Plato and Aristotle already saw the cosmos as a rational order, a living entity animated by a soul or a first principle. The universe became a system of causes, in which divine or natural reason replaced the will of the gods. In India, in China, and in the Islamic world, people also thought about the cyclicity of time and the hierarchical structure of the heavens, but according to logics of harmony rather than domination. With Copernicus, Kepler, and Galileo, the Earth lost its central place, and Newton brought this revolution to completion: the universe was now a mechanical space, governed by universal laws. Cosmology became physics.

Two preliminary remarks: first, as the bibliography is already sufficiently extensive, we have chosen to spare the reader the ethnological references we consulted, which are not central to this

work; second, the various pieces of information concerning Indigenous cosmologies are, of course, precolonial. We will see later how they have sometimes hybridized with modern Western cosmologies.

**The Inuit (circumpolar Arctic)**[7]

Geography immediately imposes a world of extreme limits: vast expanses of ice, shifting pack ice, bare tundra, and the radical alternation of the polar day and the winter night. The environment is unstable, shaped by the seasons of hunting and by the migration of marine and terrestrial animals, which directly determine collective survival. Resources are scarce but vital: seals, walruses, whales, fish, and caribou, along with snow, ice, and bone as technical materials. In this context, careful observation of the sky, the winds, the ice, and the cycles of light becomes an essential skill, both practical and symbolic.

Inuit cosmology is rooted in this constant coexistence with a dangerous yet inhabited world, where the visible and the invisible are closely intertwined. Many stories link celestial phenomena to the social and moral order: the myth of the Sun-Sister and the Moon-Brother accounts for the day–night cycles, the trajectories and the distance of the stars, while placing these movements within a story of transgression and separation. The aurora borealis are not mere physical manifestations, but the dance of the souls of the deceased, reminding people of the continuity between the living and the dead. The shaman, the *angakkuq*, moves between the layers of the cosmos to repair imbalances caused by human faults, restore harmony, and ensure the return of game. The universe thus appears as a network of relationships and reciprocities between humans, animals, spirits, and natural phenomena, where cosmology is inseparable from ethics and survival.

[7] As the bibliography is already sufficiently extensive, we have decided to spare readers references that we have consulted but which are clearly not central to this work.

**Figure 1** The circle of life drawn on the ground is associated among Native Americans with a cyclical conception of the universe, the Wakhan Tanka.

### The Lakota (North American Plains)[8]

Vast open spaces, almost infinite, made of rolling prairies, immense skies, and unobstructed horizons, where wind, light, and animal migrations structure the experience of the world. The environment is shaped by marked seasons, the course of the Sun, violent storms, and harsh winters, while traditional resources rely largely on the bison, a central animal both materially and symbolically, but also on medicinal plants, water, and fire. This life in direct contact with natural cycles gives rise to a relational cosmology, in which the universe is not a backdrop but a living fabric of connections. *Wakhan*, the sacred force, permeates everything and manifests in countless forms, without ever being reduced to a single or anthropomorphic entity. *Wakhan Tanka*, the "Great Mystery," refers both to the whole of the sacred and to the world itself, in its irreducible unity and its plurality of manifestations. The universe is conceived in circles: the circle of life,

[8] A precolonial description, of course, and the same will apply to other descriptions of Indigenous cosmologies.

seasonal circles, circles of generations, but also the sacred circle of the directions of the world, often represented by the Sacred Hoop[9], which orders space, time, and human experience. The human being is not separate from nature, but one of its relatives, engaged in relations of reciprocity with animals, plants, elements, and invisible powers. The spiritual world and the physical world are not two distinct spheres, but two aspects of the same lived reality. Rituals, dance, and prayer are not meant to dialogue with a transcendent elsewhere, but to bring the circles into accord with one another, to maintain the dynamic harmony of the whole, and to remind each person of his place within the Great Mystery.

**The Diné – often called Navajo (North American Southwest)**

They inhabit desert plateaus, canyons, mesas, and vast semi-arid expanses, where light, dryness, and strong thermal contrasts deeply shape ways of life. The environment demands constant attention to water, rare and precious, to seasonal cycles, and to local resources, combining adapted agriculture, herding, gathering, and hunting. This space is never neutral: it is symbolically structured by four sacred mountains that define Diné territory and anchor the cardinal directions, making the landscape itself a cosmological map. The cosmology is based on a narrative of emergence, the *Diné Bahane'*, the Navajo creation myth and foundational origin story, which recounts the gradual passage through several successive worlds, from ancient unstable and imperfect worlds to the present one. Each world corresponds to a stage in the establishment of cosmic, moral, and social order, marked by crises, imbalances, and readjustments. The universe is not fixed but conceived as a succession of worlds in growth, where creation and destruction are closely linked. Numbers, directions, and colors play a structuring role, connecting space, time, and human conduct. Rituals, particularly chants and sand paintings, reproduce on a small scale the structure of the cosmos in order to restore *hózhó*, the central principle of harmony, beauty, and balance. These practices are not symbolic in an abstract sense but operative:

[9] Or the "Medicine Wheel," constructed on the ground from alignments of stones, a cosmic symbol representing the order of the world, the cardinal directions, the rhythm of the seasons, and sometimes indicating the positions of the solstices. (Wikipedia)

by realigning the individual with cosmic forces, they participate in maintaining the order of the world itself.

**The Aztecs – or Mexica (Mesoamerica, Mexico)**

The Mexican high plateau is structured by lacustrine valleys, active volcanoes, and mountain ranges, with an environment that is both fertile and unstable. Intensive agriculture, based notably on maize and on cultivation on floating gardens (*chinampas*)[10], provides essential resources, while water, earth, and volcanic fire play a central role in the material and symbolic organization of the world. This close relationship with a cyclical and potentially destructive environment extends into a cosmology founded on a cosmic history of successive ages called "Suns." According to the accounts preserved, notably in the Florentin Codex[11] and the *Chimalpopoca*, the universe has undergone several creations and destructions, each corresponding to a Sun governed by its own laws. We live under the Fifth Sun, an unstable and threatened age that is sustained only through ritual sacrifice, for the cosmos requires human vital energy to continue its course. Space is organized according to four cardinal directions and a center, reflecting a dynamic universe held in balance by opposing forces. Time is fundamentally cyclical and structured by the articulation of two complementary calendars: the *tonalpohualli*, a 260-day divinatory calendar, and the *xiuhpohualli*, a 365-day solar calendar, which coordinate ritual, political, and cosmic life. Thus space and time interlock in a vision in which the order of the world depends on constant maintenance, at the cost of a cosmic responsibility assumed by humans.

**The Kogi (Colombia – Sierra Nevada de Santa Marta)**

Their geography is inseparable from their cosmology: an isolated, steep massif rising from the Caribbean Sea to the eternal snows within a few dozen kilometers, concentrating in one place all climatic and ecological zones. This exceptional environment provides varied resources, both agricultural and symbolic, but above all imposes an integrated vision of the territory, in which each

[10] A cultivable surface created in lacustrine areas.

[11] Or the Codex of Florence, a manuscript recounting the history of New Spain and serving as an encyclopedia of the Aztec world. (Wikipedia)

altitude, each spring, and each valley has a precise cosmic function. The Sierra is not simply a habitat; it is conceived as the heart of the world, a living organism whose balance conditions that of the entire Earth. In Kogi cosmology, the universe originates from *Aluna*, the matrixial Thought of the Great Mother, an original consciousness preceding all matter, all space, and all time. Before the world takes form, everything already exists in thought, as ordered potential. The cosmos is depicted as an egg or a cosmic mountain composed of superimposed layers, each corresponding to a level of the world, visible or invisible. The Sierra Nevada itself is the material expression of this cosmic structure, and the ceremonial houses reproduce its architecture, becoming operative microcosms. The *Mamos*, wise men initiated from childhood, have the role of maintaining the balance between these different levels through meditation, ritual speech, and offerings, applying the moral law inherited from the Great Mother. Any local imbalance, any human fault, resonates on a global scale, for the universe is conceived as an organic whole in which thought precedes and governs matter.

**Figure 2** In Colombia, Indigenous peoples of the south engage in a ritual involving Aluna, the Great Mother who conceived the world even before its creation.

**The Quechua, Aymara, Incas (Andes)**

They inhabit the Andes cordillera, a world of high mountains, altiplanos, deep valleys, and volcanoes, where altitude, relief, and climate impose a constant relationship with verticality. The environment is demanding but rich, based on the careful mastery of ecological tiers, terrace agriculture, the domestication of plants such as potatoes and maize, and the herding of camelids, which ensure subsistence and exchange. This material organization is embedded in a cosmology in which the polysemous concept of *pacha*[12] inseparably unites space and time, making the cosmos a living spatiotemporal continuity. The world is structured into three interdependent planes: the *hanan pacha*, the upper domain of stars, celestial phenomena, and divine powers; the *kay pacha*, the present world, that of human experience; and the *ukhu* or *manqha pacha*, the inner and deep world, associated with roots, the dead, and forces of germination. These levels are not hierarchical but in constant interaction, crossed by flows, passages, and correspondences. Every human action has cosmic repercussions, for the universe functions according to principles of cycle, complementarity, and reciprocity. *Ayni*, the fundamental law of exchange and cooperation, governs both social relations and the relationships between humans, nature, and invisible powers. Rituals, offerings, and agricultural calendars act as interfaces, intended to maintain the dynamic balance between these different planes of the pacha.

**The Yoruba (West Africa)**

They are found in a region of open forests, savannas, and riverine zones, where water, fertile soil, and dense vegetation durably structure forms of subsistence and settlement. The environment provides varied agricultural resources, a rich vegetal pharmacopoeia, and a setting favorable to ancient urban societies organized around cities, lineages, and complex cults. This social and ecological density is reflected in a cosmology in which the world is conceived as a relational continuum rather than as a space divided into sealed domains. The cosmos unfolds according to two inseparable planes: *Ayé*, the visible world of humans, animals, and everyday actions, and *Òrun*, the invisible world where the ancestors and the *orisha* reside,

[12] Which can mean Earth, world, universe, time, or epoch. (Wikipedia)

divine powers associated with the forces of nature and the principles of existence. These two spheres are never separated from one another; they constantly interpenetrate, and the harmony of the world depends on the quality of their exchanges. *Ifá* functions as a genuine ritual and cognitive technology that makes it possible to interpret signs, arbitrate imbalances, and guide human action within this cosmic fabric. Destiny, *òrí*, is not a fate imposed once and for all, but a potential negotiated through the relationships between humans, ancestors, divinities, and circumstances. The universe thus appears as a dynamic ensemble of interacting forces, neither fixed nor strictly mechanical, where balance is constructed and maintained through ritual action, speech, and moral responsibility.

**The San – or Khoisan (Southern Africa)**

Their environment is marked by contrasting and demanding settings, ranging from the semi-desert regions of the Kalahari to more open savannas, where water, rare and unpredictable, conditions the whole of social and symbolic life. The environment imposes a hunting and gathering economy based on extremely fine knowledge of animals, plants, climatic cycles, and the signs of the sky. Resources are never separated from meaning: rain, game, and human health belong to the same network of vital relationships. In this cosmology, the world is animated by ambivalent powers, often linked to water, serpents, and atmospheric phenomena, capable of bringing both fertility and danger. The central figure is *Kaggen*[13], often associated with the praying mantis, a polymorphic being who creates through transformation, transgresses boundaries, and recalls the unstable character of cosmic order. Animals, particularly the eland[14], occupy a privileged place as mediators between the planes of reality, concentrating both vital power and ritual significance. The world is traversed by an energy called *Noum*, activated during trance dances in which the shaman enters a state of vision and cosmic movement. Through this ecstatic journey, he crosses the layers of the world to restore balance, bring rain, heal illnesses, or repair broken order. The San universe thus appears fluid, unstable, and in

[13] *Kaggen* as one of the *tricksters* (a term translated in anthropology as a "mischievous demiurge," a being who plays tricks) and creators.

[14] A type of antelope; the spelling is correct.

constant metamorphosis, where health, climate, hunting, and cosmology belong to the same living continuum.

**The Ainu (Hokkaido Island – Japan – and Sakhalin – Russia)**

Cold and forested regions, mountains, fish-filled rivers, and wind-beaten coasts, where forest and water deeply structure ways of life. This environment provides essential resources such as salmon, deer, bears, wood, and plants, but also demands constant attention to seasonal rhythms and ecological balances. This intimacy with the natural environment extends into a cosmology in which the world is populated by *kamuy*, spiritual powers that manifest in concrete forms: animals, plants, landscapes, objects, or natural phenomena. The *kamuy* visit the human world by taking on a material envelope, then return to their own domain at the end of ritual exchanges. The universe is thus conceived as a system of circulation and gifts, where every hunt, every fishing expedition, every domestic fire involves a moral relationship. Offering, praying, and giving back are necessary acts to maintain the fluidity of the cosmic breath and to prevent the rupture of balance. Humans do not occupy a dominant position, but a relational place within a network of sacred reciprocity between humans and non-humans. Rituals, especially those associated with the bear or the salmon, are not gestures of domination but protocols of passage and respect, intended to ensure harmonious continuity between the worlds.

**The Aboriginal peoples (Australia)**

These peoples are spread across a continent of immense deserts, savannas, coastal regions, and tropical forests, where geography demands an extremely fine reading of the land and its rhythms. The environment, often arid and variable, provides scattered resources (water, plants, animals) whose access depends on precise knowledge of the seasons, ecological cycles, and movements. In this context, the sky is not a mere backdrop but a map, a calendar, and a living memory, inseparable from the land. The constellations are not drawn only by bright stars: some are formed by the dark regions of the Milky Way, such as the Sky Emu[15], a major figure that indicates periods of reproduction, hunting, or gathering. These celestial

[15] The second largest bird in the world, after the ostrich. (Wikipedia)

markers are directly operative, guiding everyday practices as much as mythic narratives. The Dreaming tracks (or Songlines[16]) connect terrestrial places to cosmic events: to follow a path is to reenact the journey of the ancestral beings and to keep the story of creation alive. Each site, each star, each animal is thus part of a continuous narrative and ritual network. Sky and earth respond to one another without rupture, united by song, walking, and collective memory. The universe appears as an indivisible whole, where the time of the Dreaming is not past but constantly reactivated through human actions.

**The Māori (New Zealand)**

They inhabit volcanic and mountainous islands, at the foot of which lie fertile plains and dense forests, surrounded by an omnipresent ocean that structures both resources, movements, and imagination. The environment provides wood, plants, birds, fish, and agricultural lands, but also imposes a close relationship with climatic cycles, winds, and ocean currents, essential for navigation. This immersion in an intensely living world is reflected in a cosmology founded on a generalized kinship. Everything begins with the embrace of *Rangi*, the Sky Father, and *Papa*, the Earth Mother, whose separation by their children allows light to enter the world and inaugurates movement, differentiation, and life. From this primordial act unfolds a cosmic genealogy, the *whakapapa*, which connects gods, humans, natural elements, and celestial bodies within a single lineage. Each mountain, each river, each star or atmospheric phenomenon possesses a precise lineage, which grounds knowledge, identity, and moral obligations. The cosmos is not an abstract exterior but a living kinship, engaging relationships of respect and responsibility. Rituals, chants, and navigational practices are not mere cultural traditions but acts of continuity through which humans maintain the link between worlds, honor their celestial ancestors, and inscribe their actions within the cosmic order.

[16] Songs that serve as a mental map throughout a journey. (Wikipedia)

**Figure 3** In Polynesia and Micronesia, the predominantly oceanic environment has fostered rituals and worldviews linking the ocean and the sky, notably through the stick chart.

### The Polynesians and Micronesians (Pacific)

They are confronted with a space without terrestrial continuity, composed of archipelagos scattered across an immense ocean, where the sea constitutes at once the route, the resource, and the living environment. The marine environment provides fish, shellfish, and routes of circulation, while the islands offer limited resources carefully integrated into finely balanced ecological systems. In this world without fixed landmarks, the sky and the ocean form a single field of interpretation, continuously observed and memorized. Traditional navigation, transmitted through initiation, notably through the knowledge known as *pwo*, is based on a comprehensive understanding of winds, swells, currents, birds, and stars, interpreted as the signs of a single cosmic system. Stick charts, used especially in Micronesia, materialize patterns of swell and the relationships between islands, while the star compass mentally organizes the night sky into directions and trajectories. The world is not perceived as a set of isolated points but as a living network of relationships between sea, sky, and land. Myths often evoke a common origin of the islands, emerging from a primordial ocean,

emphasizing the fundamental unity of space. The universe is thus conceived as dynamic and shifting, without an ontological separation between sky and sea, where moving through space means reading and actualizing the cosmic structure itself.

## CONCLUSION

Traditional cosmologies first conceived the world as a living being, not as an object. In Indigenous cosmologies, whether African, Native American, or Oceanian, the cosmos is an organism in balance, crossed by relationships, where humans, stars, and spirits partake of the same breath. Time is cyclical, worlds are interwoven, and the sky responds to the Earth. The universe is not something to be understood, but something to be kept in harmony. These oral and symbolic visions express a metaphysics of relation and interdependence. They belong to prescientific cosmological ontologies, distinct from and largely opposed to modern naturalist ontology.

In traditional visions, the universe is inhabited, meaningful, and alive, whereas in modern science it is matter-energy, space-time, and physical laws. Thus, from the living cosmology of ancient peoples to the relativistic and quantum universe of physicists, a continuous trajectory emerges: that of a human gaze moving from participation to distance, and then attempting to rediscover the lost unity. The universe appears in turn as an organism, a mechanism, and then as a network of information or of interwoven universes. A movement of thought that a fractal multiversal approach will naturally extend: that of a world where everything is at once parts and whole, and a reflection of the whole.

“Perceptive” cosmologies rely on, and are limited to, what is perceived; that is their starting point. The starry sky, the planets, the Moon and the Sun, and that magical band of the Milky Way. And for the sharpest eyes of the young, perhaps even faint hazy patches that will one day be called, quite fittingly, “nebulae.” There are not yet any optical instruments. Nothing else can be seen, which leads to the first interpretations of a completely flat sky: a bowl, a sphere, a vault, like a lid placed over the world. But things could not remain that way.

Perceptive cosmologies become “symbolic” precisely because interpretation is irresistibly called upon to fill the void of meaning. This sky, so immense, cannot possibly serve no purpose. It must somehow respond to human questioning. Thus humans began to create the sky.

# 2. Hybrid Cosmologies

Because of colonization, Indigenous cosmologies could not remain within their sociogeographical sanctuary. We will see that the reforming pressure of monotheistic religions (Christianity and Islam) and of modern scientific education could only influence them considerably, leading to a hybridization and often a corruption of their contents and practices.

**Dogon cosmology**

"Dogon cosmology" belongs to the Dogon people, settled on the Bandiagara Plateau in present-day Mali, in West Africa. This region was incorporated into the French colonial empire at the end of the nineteenth century, and from that time onward the Dogon were exposed to colonial administration, Catholic and Protestant missions, as well as to Islam already present in neighboring areas.

Traditional Dogon cosmology is structured around a complex cosmogonic myth centered on *Amma*, an abstract creative principle, and on the creation of the world in successive stages marked by recurring imbalances. The narrative features the *Nommo*, twin beings, aquatic and luminous, associated with speech, number, order, and the regeneration of the world. The cosmos is conceived as a hierarchical system in which the Earth, assimilated to a female body, is inscribed within a celestial order structured by cycles, directions, and numbers. Astronomical knowledge, integrated into rituals, architecture, and masks, closely links social organization, mythical time, and cosmic space.

Colonial contact gradually transformed this cosmology through a double pressure. On the one hand, Christian missions sought to marginalize cosmogonic narratives in favor of a biblical reading of the world, introducing a linear temporality and a theology of salvation foreign to the Dogon system. On the other hand, the diffuse spread of Islam led to a symbolic recomposition, with certain myths being reinterpreted in the light of monotheism. To this was added the influence of twentieth-century Western scholarship, particularly ethnology, which fixed and sometimes overinterpreted Dogon cosmology, transforming it into an object of exogenous knowledge.

The result today is a hybrid cosmology in which traditional narratives persist, but often detached from their original structuring function, coexisting with imported religious and conceptual frameworks.

**The Cosmology of the Quechua and Aymara**

In the central Andes, mainly in the territories that are now Peru and Bolivia, Indigenous cosmologies developed among Andean populations inheriting the pre-Columbian world, in the mountainous region of the Andes cordillera.

From the sixteenth century onward, these societies were conquered and administered by the Spanish Crown, accompanied by massive evangelization carried out by Catholic orders. As we have seen, traditional Andean cosmology is based on an animated and relational universe, structured around *Pachamama* (Earth-world), the *Apus* (spirits of the mountains), and a tripartite cosmos articulating the world above, the world here, and the world below. Time is cyclical, marked by the agricultural seasons, rituals, and symbolic exchanges between humans, ancestors, and natural powers. The cosmos is not separate from social life: cultivating, offering, and celebrating are ways of maintaining cosmic balance.

The Spanish conquest abruptly introduced a Christian cosmology founded on a transcendent God, a linear history of salvation, and a radical hierarchy between Creator, Nature, and Humanity.

Nevertheless, the ancient gods did not disappear but were reclassified: the *Apus* were sometimes assimilated to local saints, while *Pachamama* was tolerated as a folkloric figure or demonized depending on the context. The result was a hybrid cosmology in which Catholic rituals coexisted with reinterpreted Andean practices, often concealed or reformulated.

This hybridization was neither homogeneous nor stable: it varied according to regions, periods, and relations of power, producing a stratified symbolic universe in which Christian frameworks overlaid, without entirely erasing them, the pre-colonial cosmological logics.

### Cosmologies of Sub-Saharan African Peoples

These cosmologies encompass a vast range of societies spread across West, Central, East, and Southern Africa, among which one can cite the Yoruba, the Akan, the Kongo, the San, the Shona, and many Bantu peoples. From the fifteenth century onward, these regions gradually came into contact with European colonial powers, mainly Portugal, France, the United Kingdom, and Belgium, followed by Catholic and Protestant Christian missions, while Islam became established or strengthened across large Sahelian and coastal areas.

Traditional Sub-Saharan cosmologies generally rest on a relational and hierarchical vision of the world, in which a creative principle, often distant, coexists with a dense ensemble of spirits, ancestors, and natural forces acting within the human world. The cosmos is animated, structured by correspondences between sky, earth, the invisible world, and society, without a clear separation between nature, the sacred, and everyday life. Time is predominantly cyclical or rhythmic, linked to seasons, generations, and rituals of regeneration.

Colonization and evangelization introduced a Christian cosmology founded on divine transcendence, the linearity of historical time, and the disqualification of local spiritual mediations, often assimilated to superstition or idolatry. In many cases, ancestral figures and spirits were reconfigured as demons, secondary saints, or relegated to the sphere of folklore.

Colonial schooling and administration also contributed to this transformation by imposing rational and legal frameworks foreign to local cosmological logics. The result today is the presence of hybrid cosmologies, in which ancestral beliefs, Christianity, Islam, and modern representations of the world coexist, often in a stratified and contextual manner, without forming a unified synthesis, yet preserving a symbolic depth inherited from precolonial systems.

### Indigenous Cosmologies of North America and Canada

These cosmologies unfold among a great diversity of peoples distributed across the entire North American continent, notably the Lakota and other Plains nations, the Algonquian and Iroquoian peoples of the East, the Salish and Tlingit peoples of the Northwest Coast, as well as the Diné Navajo of the Southwest. These territories

now correspond to the political spaces of Canada and the United States, but they were colonized from the sixteenth century onward by France, the United Kingdom, and, more marginally, Spain.

Indigenous cosmologies are based on an animated and relational vision of the world, in which humans, animals, plants, ancestors, and spiritual entities all participate in the same cosmic fabric. The cosmos is conceived as a network of interactions and alliances, structured by origin narratives, seasonal cycles, and sacred places, without a strict separation between the natural world and the spiritual world. Time is predominantly circular, inscribed in the return of seasons, animal migrations, and renewal rituals.

Colonization introduced a Christian cosmology founded on divine transcendence, historical linearity, and a radical hierarchy between humans and the rest of living beings. Religious missions, boarding schools, and assimilation policies sought to eradicate cosmogonic narratives, languages, and ritual practices, relegating them to the status of archaic beliefs.

This symbolic violence led to a fragmentation of traditional transmissions. Nevertheless, Indigenous cosmologies did not disappear: they recomposed themselves, sometimes clandestinely, sometimes by integrating reinterpreted Christian elements. The result today is the presence of hybrid cosmologies, marked both by the persistence of relational conceptions of the cosmos and by the enduring imprint of Western religious and institutional frameworks.

**The Cosmology of Japan**

The cosmology of Japan developed within the Japanese archipelago in East Asia, within an insular culture that remained relatively isolated for a long time before entering sustained contact with Western powers from the nineteenth century onward, notably with the forced opening of the country by the United States in 1853, followed by the rapid modernization of the Meiji era. Unlike many colonized societies, Japan was not directly dominated politically by a European power, but it nevertheless underwent major Western cultural, scientific, and ideological pressure.

Traditional Japanese cosmology is based on Shinto, an indigenous religious system founded on an animated and immanent vision of

the world, in which the *kami*, sacred presences or powers, inhabit natural phenomena, places, ancestors, and cosmic forces. The cosmos is conceived as a living continuum, without a radical separation between nature, society, and the sacred, and without a single narrative of creation *ex nihilo*.

From the sixth century onward, this cosmology was enriched and transformed through the integration of Buddhism arriving from China and Korea, introducing cyclical conceptions of time, impermanence, and the multiplicity of worlds. The Shinto-Buddhist ensemble thus formed, long before Western influence, an already hybrid but coherent cosmology.

The arrival of modern Western knowledge in the nineteenth century, along with mechanistic science and a disenchanted vision of nature, profoundly modified cosmological frameworks without abolishing them. Shinto was partly instrumentalized by the modern state, while scientific cosmology became dominant in education and institutions. The result is a contemporary hybrid cosmology in which origin myths, Shinto animism, Buddhist heritage, and the scientific representation of the universe coexist, not as a complete synthesis, but within a lasting cultural stratification.

**The Cosmology of China**

The cosmology of China developed across the vast territory of ancient China in East Asia, within a civilization that has been continuous since the second millennium BCE. Unlike many regions of the world, China was not permanently colonized by European powers, but from the nineteenth century onward it experienced strong imperial, commercial, military, and cultural pressures from Western powers, notably the United Kingdom, France, and later the United States, as well as from Japan.

Traditional Chinese cosmology rests on a fundamentally immanent and processual vision of the cosmos. The universe is conceived as a dynamic order governed by the *Dao*, an undifferentiated cosmic principle, and structured by the interactions of *Yin* and *Yang* as well as by the Five Phases. Heaven, Earth, and humanity form a harmonic continuum, without a transcendent creator and without an ontological rupture between nature and society. Time is cyclical and rhythmic, based on alternations,

correspondences, and transformations. This cosmology permeates philosophical thought as well as traditional medicine, politics, and astronomy.

From the nineteenth century onward, the forced introduction of Western science, Christianity, and a mechanistic vision of the universe challenged these ancient frameworks, particularly within education and institutions. The twentieth century deepened this rupture with the official condemnation of traditional cosmologies in favor of scientific and ideological materialism.

The result today is a hybrid cosmology in which modern scientific representations coexist with older cosmological schemes that remain present in culture, symbolic practices, and certain contemporary philosophies, without the reconstitution of a unified system, but within a deeply stratified cultural continuity.

## CONCLUSION

Hybrid cosmologies differ from original Indigenous cosmologies in that they constitute neither closed systems nor stabilized syntheses, but stratified historical configurations resulting from prolonged asymmetrical contacts with Western religious, political, and epistemic powers.

They arise less from a fusion than from a superposition of heterogeneous frameworks of thought, often compartmentalized according to social, ritual, or institutional contexts. Ancient cosmological structures partially persist within them, but stripped of their global explanatory function of the world, relegated to symbolic, identity-based, or cultural registers, while Western models impose themselves in the description of the physical world, of time, and of space.

These hybrid cosmologies thus testify to a lasting moment of transition, in which visions of the cosmos belonging to different, sometimes contradictory logics coexist without unifying resolution. They reveal less a conceptual weakness than an intermediate historical state, marked by the progressive dissociation between lived cosmology, symbolic cosmology, and scientific cosmology, a prelude to the generalized adoption of modern cosmological frameworks.

More broadly, in perceptual and symbolic cosmologies (hybridized or not), the world first presents itself as a nearby, readable, and inhabited space, stretched between a flat or weakly extended Earth and a low celestial vault, almost within reach. From this emerges a double centering: geocentric, because the Earth constitutes the absolute reference plane, and anthropocentric, because human experience organizes the totality of meaning. The sky is never an abstract background; it is observed, scrutinized, and memorized, especially in environments where the horizon is open (deserts, steppes, oceans), becoming an operational tool. Bright stars, the dark regions of the Milky Way, solar and lunar cycles, and celestial directions serve to mark time, guide movements, order the seasons, navigate, or hunt. The celestial vault is not distant: it is functional, incorporated into practices and survival.

From these concrete relations arise interpretations organized into narratives, myths, and coherent cosmologies. The dead, the ancestors, invisible powers, and specialized officiants play a central role, ensuring continuity between the planes of the world. The shaman, the sage, the diviner, or the priest does not mediate with an "other world" radically separated, but circulates within a continuous cosmic space where the visible and the invisible coexist.

These interpretations are inseparable from everyday life: they involve the health of bodies, the fertility of soils and of women and female animals, the abundance of game, the coming of rain, or the calming of storms. Cosmic ethics are never abstract; they regulate relations between humans, animals, plants, natural phenomena, and fundamental elements, defining misconduct, imbalance, repair, and harmony as concrete realities with immediate consequences.

To this network of relations is added a more abstract level, without breaking with the previous one: that of thought, invisible laws, and organizing principles. Reciprocity, cycles, causes and effects, exchanges, and complementarity structure the universe as much as human societies. Embryonic forms of religion emerge, carried by trained officiants responsible for maintaining cosmic order through rituals, chants, dances, and symbolic gestures. The universe then becomes a narrative that is both historical and cosmological, made of creations, destructions, successive emergences, filiations, and ages of the world. The images that represent it (cosmic egg, central mountain, concentric circles,

superimposed layers) express the same intuition: that of a stratified, living reality in which the invisible never denies the visible but deepens it.

If one attempts to estimate, even roughly, the size and shape of the universe in these cosmologies, one observes a strong cosmological parochialism. The habitable world rarely extends beyond a few dozen or a few hundred kilometers around the human group, sometimes reaching the limits of the known territory or of mastered maritime routes. The celestial vault is conceived as a finite sphere, with a radius of a few kilometers to a few dozen kilometers, supported by pillars, mountains, or invisible layers, and directly enclosing the Earth. The universe is closed, finite, often circular or ovoid, structured in stacked levels or concentric circles, with no idea of spatial infinity. This parochialism is not ignorance but coherence: the universe has the size of what matters, of what acts, and of what engages human responsibility. It is scaled to relation rather than abstraction, and its shape reflects less a geometry than the lived cartography of a world where surviving, understanding, and acting are one and the same.

One may say that at this stage perceptual and symbolic cosmologies have already done almost all the work. They have woven a readable, relational, inhabited world, where sky, Earth, the living, and the dead form a continuum of interactions regulated by narratives, rites, and balances. Only one rather discreet step remains for these relations to stabilize, to be conceptualized more firmly, and to concentrate around figures, principles, or powers more clearly identified.

We will see that the transition toward relational theological cosmologies therefore does not break with this perceptual foundation; it tightens it, sometimes hierarchizes it, and gives it a more enduring moral and narrative coherence. The world remains relation, but relation begins to organize itself around instances more persistent than phenomena alone, as if the universe sought less to be read than to be guaranteed by principles, figures, or powers capable of sustaining the order that is considered immutable.

# 3. Intermediate cosmologies

Relational theological cosmologies, which we will examine next, did not emerge all at once, nor through a clear break with earlier visions of the world. They belong to a continuum of representations in which sensory perception, mythic symbolism, philosophical rationalization, and the first attempts at a conceptual structuring of the universe gradually intermingle.

Between the purely perceptual and symbolic cosmologies we have just seen, arising from an immediate relationship with the sky and nature, and the properly relational theological cosmologies, which articulate an ordered cosmos with an active, personal, or rational divine principle, there extends a vast intermediate zone of thought.

Within this intellectual space, many thinkers of Antiquity developed conceptions in which the universe was already understood as an order, a coherent whole, sometimes animated or governed by an abstract principle, without this principle yet taking the form of a relational god in the later theological sense. These intermediate conceptions thus prepare, step by step, the emergence of structured geocentric and later heliocentric cosmologies, by integrating questions concerning the form of the universe, the place of the Earth, the hierarchy of the heavens, and the rationality of the world.

This chapter will follow a conceptual rather than chronological path, highlighting the continuities, shifts, and successive recompositions that will lead, beginning with the Renaissance, to the disappearance of celestial vaults and spheres, and to the appearance of an open universe populated by stars, the Milky Way, and nebulae, a prelude to the cosmological revolutions of the nineteenth and twentieth centuries.

**Anaximander (circa -610/circa -546)**

The Greek philosopher Anaximander offers one of the earliest known attempts to conceive the universe as a coherent whole governed by impersonal principles rather than by anthropomorphic divine figures. With the apeiron, the unlimited or the indeterminate, he introduces a radically new cosmological principle, neither an

identifiable material element nor a personal divinity, but an abstract source of all things. The cosmos is no longer the result of a capricious divine will, but the effect of a necessary process, in which beings emerge, differentiate, and then return to the indeterminate according to a form of "cosmic justice."

**Figure 4** In the *Apeiron* of Anaximander, an abstract cosmological principle emerges, explaining the arising of beings as a necessary process.

This idea of justice, often expressed in quasi-legal terms, reflects a profound rationalization of the order of the world, in which imbalances are compensated over time. The Earth itself is no longer supported by a god, an animal, or a mythical pillar, but remains in equilibrium, suspended in space, by symmetry and necessity, which constitutes a major break with earlier mythological cosmologies and anticipates, in a still intuitive way, the idea that a body does not need support to remain in place, very distantly foreshadowing Newtonian inertia. The sky and the stars belong to a natural order that can be explained, even if the precise mechanisms remain largely speculative.

Anaximander thus inaugurates a cosmology in which the universe is conceived as autonomous, governed by internal laws,

while still retaining a strong symbolic dimension inherited from myth. His thought occupies a typically intermediate position: no longer religious in the traditional sense, not yet scientific in the modern sense, but already engaged in an abstract conceptualization of the cosmos. In this sense, it opens the way to later conceptions in which the order of the world can be related to a rational, then theological, principle, without returning to the narrative gods of archaic traditions.

**Pythagoras (circa -570/circa -495)**

Pythagoras occupies a singular place in the history of intermediate cosmologies, by introducing a reading of the world in which the cosmic order is fundamentally mathematical in nature. The cosmos is no longer merely a set of objects arranged in space, but a harmonic structure governed by numerical relations, perceptible notably in music and transposable to the universe as a whole. This identification of number as the organizing principle grants the world an abstract intelligibility that goes beyond mythic symbolism while retaining a strong sense of the sacred. The universe is conceived as an order, a kosmos in the strict sense, that is, a beautiful and just arrangement, in which each thing finds its place according to precise proportions.

Sphericity, attributed both to the Earth and to the heavens, participates in this search for formal perfection, the sphere being regarded as the most accomplished geometric figure. Pythagorean geocentrism is not merely a matter of observation or tradition, but is inscribed within a symbolic hierarchy in which the center possesses an ontological and cosmological value. The famous idea of the "harmony of the spheres," even if it is not formulated in a uniform way in the sources, expresses this conviction that celestial motions obey laws analogous to those of music.

The divine, for Pythagoras, is not absent, but manifests itself through the very order of the world, immanent in mathematical structures rather than in the form of acting gods. This cosmology thus establishes a decisive mediation between myth, metaphysics, and abstract rationality. It prepares the ground for later conceptions in which the universe can be understood as intelligible by essence, a prerequisite both for relational theological cosmologies and for future scientific descriptions of the world.

**Heraclitus (circa -544/circa -480)**

The Greek philosopher Heraclitus proposes a radically dynamic cosmology, in which the universe is never a state, but a process. The cosmos is conceived as an order in becoming, structured by the *Logos*, a principle that is at once rational, immanent, and universal, which governs the ceaseless transformations of the world. Nothing is stable, nothing is definitively constituted: everything arises through tension, opposition, and transitio[17], according to a common law that runs through both nature and human experience.

Fire, often presented as the primordial principle, should not be understood as a simple material element, but as the metaphor of a world in constant combustion, of a fundamentally changing reality. This vision breaks with cosmologies based on the permanence of being or on fixed structures, and introduces the idea of a profound unity of reality through the multiplicity of phenomena.

The cosmic order is not imposed from the outside by a personal divinity, but manifests itself in the internal coherence of becoming itself. The *Logos* is neither a creator god nor a relational providence, but a diffuse rationality that most people ignore despite its evident presence. Heraclitus thus occupies a decisive intermediate position: he discards mythic narratives while rejecting a static or strictly geometrical conception of the cosmos.

The universe is intelligible, but this intelligibility is inseparable from conflict, transformation, and instability. This cosmology of becoming indirectly prepares later lines of thought in which the order of the world will be conceived, no longer as an immobile architecture, but as an immanent law governing change, without yet leading to a structured relational theology.

**Parmenides (early 5th century BCE)**

Parmenides occupies a paradoxical and decisive position in the history of intermediate cosmologies, by proposing a vision of the cosmos founded on the absolute primacy of Being. Against the evidence of the sensible world, marked by change, multiplicity, and becoming, Parmenides asserts that only Being is, and that it is one, immobile, eternal, and homogeneous. The true cosmos is therefore

[17] In a river, one never bathes twice in the same water.

not the one perceived by the senses, but the one grasped by reason when it turns away from deceptive appearances.

This requirement of logical coherence leads to the exclusion of all birth, all destruction, and all movement, since to think non-being is already a contradiction. The Parmenidean universe is thus a closed totality, perfectly rational, whose structure belongs less to descriptive cosmology than to ontology. The world of becoming, that of phenomena, is not denied as experience, but relegated to the level of opinion, a plausible discourse, but not a true one.

In this sense, Parmenides introduces a lasting fracture between intelligible reality and the sensible world, a fracture that will profoundly shape all subsequent philosophy. His thought belongs neither to myth nor to a relational theology, but to a radical rationality that absolutizes the requirement of non-contradiction.

This cosmology of immobility, seemingly foreign to any physical description of the world, nevertheless plays a fundamental role in the history of ideas by forcing later thinkers to position themselves in relation to the problem of change. Parmenides does not offer a cosmic model in the astronomical sense, but he imposes a conceptual framework within which any cosmology must henceforth justify the possibility of motion, time, and plurality without abandoning rationality.

**Empedocles (circa -490/circa -430)**

Empedocles develops a cosmology that explicitly seeks to reconcile the rational requirement inherited from Parmenides with the evidence of change emphasized by Heraclitus. To resolve this tension, he introduces the theory of the four fundamental elements, eternal and indestructible, whose combinations account for the diversity of beings and the transformations of the world. Becoming is no longer a matter of creation or annihilation, but a play of mixtures and separations among immutable principles.

To these elements are added two antagonistic cosmic forces, Love and Strife, which govern the unification and dissociation of matter. These forces, often personified, retain a mythic coloring while playing a precise conceptual role in explaining the cosmos. The universe is conceived as cyclical, alternating phases dominated by Love, in which unity prevails, and by Strife, in which multiplicity

and separation assert themselves. This cosmic cyclicity makes it possible to integrate change without calling into question the eternity of the primary principles.

Empedocles thus occupies a typically intermediate position: he rationalizes myth without abolishing it, and he naturalizes change without abandoning an overall cosmic structuring. The divine is no longer an external agent governing the world, but diffuses into the very forces that organize nature. His cosmology offers an explanatory model of the sensible world while retaining a strong symbolic dimension, making it an essential milestone in the transition between mythic cosmologies, philosophical speculation, and future theological or scientific elaborations.

**Anaxagoras (circa -500/circa -428)**

Anaxagoras introduces a decisive distinction in the history of intermediate cosmologies by clearly separating the ordering principle of the world from the material elements that compose it. With the *Nous*, the Intellect, he affirms the existence of an autonomous rational principle at the origin of the organization of the cosmos, without, however, attributing to it the features of a personal or relational divinity. The world is made up of an infinity of qualitatively distinct seeds, originally mixed together, which the *Nous* sets in motion and orders through an initial impulse. This intellectual intervention is neither continuous nor providential: once motion is initiated, natural processes unfold according to their own laws. Anaxagoras thus proposes a cosmology in which the rationality of the world does not reside in matter itself, but in a separate principle that brings it into order.

Geocentrism remains, but it is now situated within a more abstract explanatory framework, in which celestial phenomena are interpreted in a naturalistic way, to the detriment of mythological narratives. The Sun, the Moon, and the stars are no longer gods, but material bodies subject to physical causes, marking a major cultural and religious break.

The Anaxagorean *Nous* does not enter into dialogue with the world; it neither judges nor governs morally, but grounds the intelligibility of the whole. This conception occupies a pivotal position between a cosmology still marked by symbolism and the

emergence of a fully rationalized understanding of the cosmos. It prepares both the great later metaphysical syntheses and the possibility of a scientific reading of the universe, while remaining foreign to a relational theology in the strict sense.

### Plato (circa -428/circa -347)

The Greek philosopher Plato proposes, with the Timaeus[18], one of the most structured and influential cosmologies of Antiquity, occupying a pivotal position between philosophical speculation, mathematical symbolism, and the beginnings of rational theology. The cosmos is conceived as a living being, unique, endowed with a soul and an intelligence, formed in the image of the intelligible model constituted by the "Forms"[19].

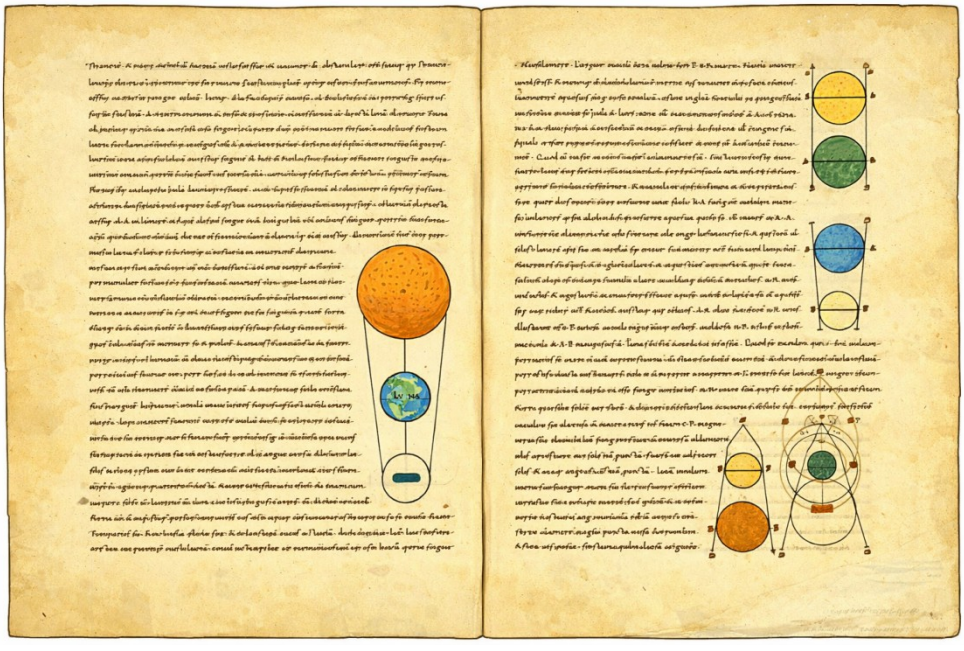

**Figure 5** The Timaeus of Plato in a Latin translation. In it, he presents a well-structured, geocentric cosmology that would influence ancient and medieval cosmologies, and extend its impact into the Renaissance.

[18] A philosophical text in which Plato sets out his cosmology.

[19] The Forms are intelligible, eternal, and immutable realities that constitute the true being of things. They are not ideas in the modern psychological sense, nor mental representations, but objective forms existing independently of the sensible world and of the human mind.

The Demiurge is not a creator god *ex nihilo*, but a divine craftsman who orders a preexisting chaotic matter by conforming it to rational and mathematical principles. This operation confers upon the world both purpose and internal coherence, without invoking a capricious or narrative will. The world soul, prior to bodies, ensures the dynamic unity of the cosmos and grounds the intelligibility of its movements, particularly those of the stars.

Platonic geocentrism is inscribed within a cosmic hierarchy in which the Earth occupies the center not by empirical privilege[20], but by virtue of the overall order of the Whole. The circular and regular motions of celestial bodies express the perfection of the intelligible order, while the sublunary world remains the domain of imperfection and becoming.

The divine, for Plato, is no longer external to the world nor simply immanent: it manifests itself in the very order of the cosmos, conceived as a rational organism. This cosmology goes beyond purely naturalistic conceptions while refusing a relational theology in the strict sense, since the Demiurge does not maintain a historical or moral relationship with human beings. By offering a lasting model of an ordered, intelligible, and purposive universe, this cosmology will exert a considerable influence on later cosmologies, in Antiquity, the Middle Ages, and the Renaissance.

**Aristotle (circa -384/circa -322)**

Aristotle develops a systematic cosmology that will dominate Western thought for nearly two millennia, closely articulating physics, metaphysics, and observation of the natural world. The Aristotelian cosmos is finite, closed, and ordered, structured into a rigorous hierarchy of regions and motions.

The Earth occupies, immobile, the center of the universe, surrounded by concentric celestial spheres carrying the Moon, the Sun, the planets, and the fixed stars. This organization rests on a fundamental distinction between the sublunary world, subject to

[20] Empirical means relying only on direct and natural experience (what is observed), and not on theory, reasoning, or experimentation. This term will be used very frequently in this book. Remember: « empirical = what is observed ».

change, generation, and corruption, and the supralunary world, perfect, eternal, and governed by uniform circular motion.

Celestial bodies are not composed of the four terrestrial elements, but of a specific substance, ether, incorruptible and naturally endowed with circular motion. The unmoved mover, the ultimate principle of this cosmology, is not an efficient cause acting upon the world, but a final cause: it moves the universe as an object of desire and intellection. It eternally thinks its own thought, without direct relation to the world, without creation or providence in the later theological sense.

Cosmic order thus results from a natural necessity oriented toward ends, rather than from a personal divine will. This conception grants the cosmos a total intelligibility, in which each thing has a determined place, nature, and purpose. Aristotle thus proposes a deeply rational cosmology, non-theological in the relational sense but strongly teleological, which will constitute the major framework of medieval cosmologies, both philosophical and theological, before being progressively challenged beginning with the Renaissance.

**Cicero (circa -106/circa -43)**

The Roman philosopher Cicero occupies a role of mediator and transmitter in the history of ancient cosmologies, reformulating for the Roman world the major Greek conceptions, mainly Platonic and Stoic[21]. His vision of the cosmos rests on the idea of a rational and intelligible order, inscribed in the very nature of the world and accessible to human reason.

The universe is neither the product of chance nor a mere blind mechanism, but a coherent whole governed by an immanent rationality, which Cicero readily associates with a diffuse providence. This providence is not that of a personal god intervening in history, but a cosmic intelligence that ensures the harmony of the Whole and the fittingness of its parts. The cosmos thus appears as a purposive system, in which natural order reflects a moral order, making it possible to articulate cosmology, ethics, and politics.

[21] Stoicism, as referred to by Cicero, is a philosophy of life consisting in the lucid acceptance of a cosmos already structured by reason and necessity.

An heir to Platonism, Cicero takes up the idea of a world ordered according to higher rational principles, while integrating the Stoic influence of an immanent cosmic *logos*. The sky and the stars play an exemplary role, manifesting through their regularity the perfection of universal order. Geocentrism remains implicit, but it is less central than the conviction that the world forms an intelligible and norm-governed whole.

Ciceronian cosmology does not bring significant scientific innovation, but it plays a decisive role in the diffusion of a worldview in which reason, nature, and the divine are not separated. It thus prepares the ground for later relational theological cosmologies by establishing the idea that the order of the cosmos can be interpreted as the expression of a rational intention, without yet breaking with a largely philosophical and moral conception of the universe.

**Seneca (circa -4/65)**

The Roman Stoic philosopher Seneca fully belongs to the Stoic tradition while giving it a particularly explicit moral and cosmological inflection. For him, the cosmos is a rational and animated whole, permeated by an immanent reason that orders and governs it from within.

This cosmic rationality manifests itself in the form of a universal natural law, to which both physical phenomena and human actions are equally subject. According to this law, the universe is neither chaotic nor indifferent: it constitutes a coherent and necessary system, in which each event finds its place within a global chain of causality.

The divine is not separate from the world, but is identified with the very order of nature, with this cosmic reason that permeates all things. Seneca readily speaks of "providence," but it is a diffuse, non-interventionist providence, which does not suspend the laws of the world, but is expressed through them.

Geocentrism remains the implicit framework of his cosmology, but the emphasis clearly shifts from astronomical structure to the rational and moral meaning of the universe. The stars, through their regularity, bear witness to the perfection of cosmic order and serve as a model for the constancy that human beings must seek. This

vision gives the world both a necessary and meaningful dimension, in which human freedom consists not in opposing destiny, but in rationally consenting to the order of the Whole.

Seneca thus occupies a transitional position: his cosmology remains philosophical and immanent, but already foreshadows more clearly providential conceptions, in which the order of the cosmos can be interpreted as the expression of an intelligible divine intention.

## CONCLUSION

What these precursors reveal, overall, is less a linear progression than a long process of displacing the attributes of the divine, without ever truly questioning their legitimacy. Ancient philosophy establishes an intermediate cosmological principle, at once abstract and still imbued with intentionality: necessity, cosmic justice, *Logos*, *Nous*, world soul. The world ceases to be governed by narrative gods, yet it continues to be conceived as bearing meaning, purpose, and sometimes even moral rationality. Mythic figures are replaced by more elegant principles, but the idea is preserved that an order "must" exist, that it is intrinsically good, harmonious, or perfect, often at the cost of *ad hoc* hypotheses that give the illusion of explanation. Aristotelian ether, the perfection of the supralunary realm, or the animation of the cosmos play this role: not so much to explain the world as to render it intellectually and existentially acceptable.

At the same time, certain decisive intuitions nevertheless emerge, such as the Earth suspended in space, the emergence of a mathematical order, or the possibility of an intelligibility independent of myths, while powerful parochial frameworks persist, in particular geocentrism and the projection of human categories (will, desire, intelligence) onto the cosmos itself.

It is precisely against this ambivalent heritage that the relational theological cosmologies of the Renaissance and the classical age will be constructed. With Copernicus, the center will cease to be an ontologically privileged place, and the structure of the world will begin to be described independently of the human position. Galileo will carry out an even more radical break, by dissociating physical description from moral purpose, and by substituting for the

symbolic qualities of the cosmos an operational mathematical language. Giordano Bruno will push this decentering to its metaphysical consequences, dissolving the spheres, opening space to infinity, and stripping the world of any intrinsically human hierarchy.

The relational theology that then emerges no longer consists in attributing to the cosmos an anthropocentered intention or perfection, but in conceiving a God separate from the physical world, whose relation to creation is no longer inscribed in the very structure of the heavens. The cosmos finally becomes an autonomous object, silent as to meaning, and it is precisely this silence that makes a true scientific cosmology possible. Where intermediate conceptions still projected the human into the universe, modern cosmologies begin to accept a world that has nothing to say about us. A necessary condition for theological relation, if it persists, no longer to be confused with a disguised cosmology.

# 4. Relational Theological Cosmologies

For these philosophers, the cosmos is conceived as an ordered totality, progressively objectified, structured by spheres that envelop the Earth, according to a hierarchical structure of nested layers, with divinity relegated to the infinite exterior.

Geocentrism is predominant; however, the Earth is no longer reduced to a local landscape. It encompasses everything that the geography of the time can provide in the way of truncated continents, at the limits of exploration, around a geographically hegemonic Mediterranean basin. We shall see that, up to Newton, heliocentric and mathematizable approaches remained exceptional. The cosmologies thus developed claimed to be rational, scientific, and universal, addressing humanity as a whole.

These cosmologies are called relational because their ultimate principle is not isolated from the world, but engaged in a constitutive relationship with it. The divine is not merely a first cause or an external architect; it is that with which the world stands in a permanent relation, that from which it proceeds, on which it depends, or in which it participates. In Plato, the sensible world is in relation to the Forms; in Aristotle, it is ordered toward the prime mover; in Neoplatonic or medieval traditions, being emanates, becomes hierarchized, and continually refers back to its principle. Even where there is transcendence, it does not break the link; it grounds it. The cosmos thus remains structured by relations of origin, dependence, finality, or participation, rather than as an autonomous whole governed by impersonal laws. Cosmologies developed in this way therefore present themselves as relational, rational, scientific, and universal, addressing humanity as a whole.

**Eudoxus of Cnidus (circa -408/circa -355)**

With Eudoxus of Cnidus, cosmology reaches a decisive moment in which the order of the heavens ceases to be conceived in mythical or symbolic terms and becomes an abstract, autonomous geometric system governed by mathematical relations. His model of homocentric spheres, all centered on the immobile Earth, constitutes

the first systematic attempt to account for planetary motions through pure kinematics, without recourse to divine wills or occult forces. Each celestial body is carried by a set of concentric spheres animated by uniform rotations, whose combination explains the observed trajectories, including apparent retrogradations [22] (foreshadowing Ptolemaic epicycles).

Eudoxus's cosmos is thus relational in the strict sense: it is not the bodies that possess their motions in themselves, but the geometric relations between spheres that produce the visible order of the heavens. This construction inaugurates a cosmology in which regularity becomes intelligible through reason alone, while still preserving a normative dimension: the heavens are perfect because they are reducible to uniform circular motions.

Geocentrism here is not a naïve belief, but a structural requirement linked to the symmetry and coherence of the system. The cosmos appears as an abstract machine ahead of its time, entirely determined by formal relations rather than as a stage for divine interventions. In this sense, Eudoxus prefigures both Greek mathematical astronomy, culminating in Ptolemy, and a conception of the world in which cosmic order is immanent, intelligible, and grounded in the very structure of relations, already announcing a complete rationalization of the heavens.

**Aristarchus of Samos (circa -310/circa -230)**

With Aristarchus of Samos, cosmology undergoes a radical conceptual break, without equivalent in Antiquity, through the explicit introduction of a heliocentric model in which the Earth becomes a moving body among others. This displacement of the center of the world is not anecdotal: it overturns the cosmic hierarchy inherited from symbolic geocentrism and opens the possibility of an order of the heavens grounded no longer in the

[22] Retrogradation is an apparent motion by which a planet seems, as seen from Earth, to slow down, come to a halt, then temporarily move backward relative to the background of the fixed stars, before resuming its usual direct motion. This effect is not real, but results from the combination of the relative motions of the Earth and the observed planet.

ontological centrality of the Earth, but in a simpler and more coherent geometric rationality.

Aristarchus conceives a cosmos in which the daily rotation of the heavens is attributed to the rotation of the Earth upon itself, and in which planetary motions are organized around the Sun, anticipating Copernicus's insights by nearly eighteen centuries. Yet this cosmos remains finite, enclosed, and inscribed within a sphere of fixed stars, whose extreme remoteness is invoked to explain the absence of observable stellar parallax.

The central Sun is not yet a dynamic center in the modern sense, but a geometric and ordering center, ensuring a better intelligibility of motions. Aristarchus's cosmology thus remains relational and theoretical, detached from any explicit theology, yet it comes into direct tension with Aristotelian physics and with the cosmological common sense of his time.

His heliocentrism, too far ahead of the available conceptual frameworks, would remain marginal, almost clandestine, cited more often to be refuted than to be developed. Nevertheless, it stands as a striking demonstration that the order of the cosmos can be conceived independently of any human or terrestrial centrality, inaugurating a major conceptual possibility: that of a universe in which the position of the observer no longer carries any ontological privilege.

**Claudius Ptolemy (circa 100/circa 170)**

With Claudius Ptolemy, ancient cosmology reaches an unprecedented level of formal completion, with a fully mathematized geocentrism that aims to be both descriptively accurate and conceptually coherent. In his book the Almagest, the cosmos is conceived as a closed system of nested spheres, centered on an immobile Earth, around which the motions of the Sun, the Moon, and the planets are organized through a sophisticated geometric apparatus combining deferents, epicycles, and equants[23].

[23] Déférents, épicycles et équants sont un ensemble de dispositifs géométriques introduits dans l'astronomie antique, notamment chez Claude Ptolémée, pour rendre compte avec précision des mouvements apparents des planètes. Le déférent est le cercle principal centré approximativement sur la Terre, sur lequel se déplace le centre d'un cercle

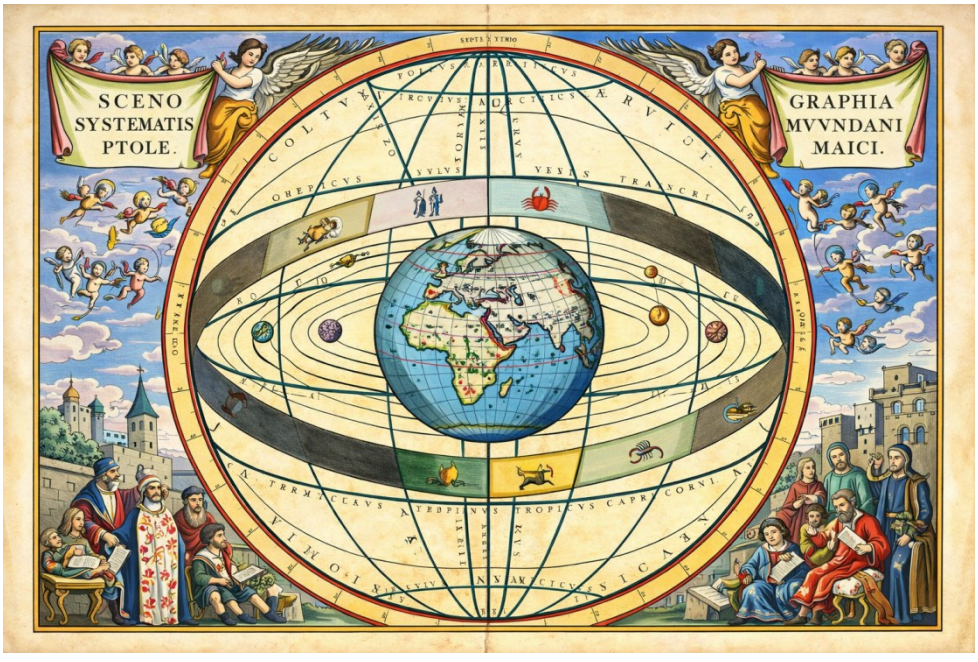


**Figure 6** For Ptolemy, geocentrism is mathematized. The cosmos is conceived as a closed system of nested spheres, centered on an immobile Earth, around which the motions of the celestial bodies are organized according to a complex geometry.

The aim is not to describe the ultimate physical reality of the world, but to save the phenomena, that is, to account with precision for the observed positions of the celestial bodies through uniform circular motions, a normative principle inherited from the Greek tradition.

The use of epicycles makes it possible to explain variations in apparent speed and retrogradations, at the cost of an increasing complexity accepted as the price of predictive accuracy. The Ptolemaic cosmos is deeply relational: observable trajectories are not attributed to forces or dynamic causes, but to the regulated composition of ideal motions within a geometrically structured space.

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secondaire, l'épicycle, parcouru par la planète elle-même. La composition de ces mouvements circulaires explique les variations de vitesse apparente et les rétrogradations. L'équant est un point décalé par rapport au centre du déférent à partir duquel le mouvement angulaire est supposé uniforme, introduisant une correction mathématique supplémentaire.

This construction establishes a clear separation between mathematical astronomy and natural philosophy, Ptolemy deliberately leaving open the question of the ontological reality of his devices. The world remains finite, hierarchical, enclosed by the sphere of the fixed stars, the ultimate boundary of cosmic order and the guarantor of its stability.

This model, of remarkable operational power, would dominate for more than fourteen centuries, not because it is naïve or dogmatic, but because it constitutes an extraordinarily effective synthesis of observation, calculation, and formal intelligibility. With Ptolemy, the cosmos becomes a self-sufficient mathematical architecture, in which the order of the heavens resides entirely in the rigor of geometric relations, without any necessary appeal to direct divine causality.

**Aryabhata (476/550)**

With Aryabhata, Indian cosmology reaches a high level of mathematical formalization while freeing itself from many naïve intuitions about the structure of the world. He explicitly affirms the sphericity of the Earth and explains the alternation of day and night by its rotation upon itself, thereby overturning the idea of a sky revolving around an immobile observer. This point is decisive: the apparent motion of the celestial bodies is already interpreted as a perspective effect linked to the motion of the terrestrial observer, an intuition of remarkable modernity.

Aryabhata's system remains geocentric in its overall organization, but it is no longer an ontological or symbolic geocentrism. It is a consciously adopted mathematical frame of reference, chosen for reasons of calculation and prediction. Planetary motions are described using precise trigonometric models, incorporating epicycles and corrective parameters, with great computational efficiency.

The cosmos is no longer conceived as a theological hierarchy of spheres animated by divine wills, but as a regular order expressible in numbers, cycles, and relations. The Earth, although central in the calculations, is no longer privileged from a dynamical point of view: it is a body among others, subject to common laws.

This cosmology is part of a learned tradition in which astronomy, mathematics, and the calculation of time (calendars, eclipses) are closely linked, without a sharp separation between science and metaphysics, yet without direct divine intervention in the explanation of phenomena.

Aryabhata thus proposes a deeply relational world, in which celestial appearances result from the combination of real motions and the observer's point of view, anticipating a relativized conception of motion that would, much later, find explicit formulation in modern astronomy.

**Zhang Heng (78/139)**

In ancient China under the Han dynasty, cosmology develops as a thought of order rather than as an abstract metaphysical speculation. The heavens are conceived as spherical or semi-spherical, depending on the models, enveloping a central Earth, flat or slightly convex, without this centrality carrying an ontological value comparable to Greek geocentrism.

The cosmos is above all a regular, cyclical system, founded on correspondences between heaven, Earth, and human society. Astronomy is inseparable from imperial administration: observing the stars, measuring time, predicting eclipses or celestial anomalies, is a major political responsibility, since the heavens are perceived as the mirror of moral and institutional order.

Zhang Heng embodies this scholarly approach by combining precise observation, mechanical modeling, and instrumentation, with devices designed to represent the motion of the heavens in a concrete and intelligible way. Celestial phenomena are not explained by personal gods, but by principles of harmony, qi, and regulation, inscribed within a relational cosmology in which each level of reality resonates with the others.

The heavens are neither transcendent nor creative, but normative. The world thus appears as a closed and intelligible system, not through geometric reduction, but through functional correspondences, where astronomy serves less to decenter humanity than to inscribe its action within a regulated and readable cosmic order.

**Nasir al-Din al-Tusi (1201/1274)**

With Nasir al-Din al-Tusi, medieval Islamic cosmology reaches a point of critical sophistication in which the Ptolemaic system is preserved while being deeply reformed from within. Al-Tusi remains geocentric, but his aim is no longer to multiply mathematical artifices in the name of predictive efficiency: he seeks to restore a conceptual coherence between astronomical models and the physical principles inherited from Aristotle.

His major contribution, the famous "Tusi couple,"[24] shows that a combination of two uniform circular motions can produce an oscillating linear motion, making it possible to account for certain planetary inequalities without resorting to the equant, deemed problematic from a physical standpoint. This innovation marks an explicit attempt to partially eliminate the most *ad hoc* Ptolemaic devices, in favor of geometric constructions more acceptable from the point of view of underlying principles.

Al-Tusi's cosmos remains closed, ordered in spheres, but it is now subject to an increased demand for internal rationality: mathematics must no longer merely "save the phenomena," it must also be compatible with a minimal physical intelligibility. The Earth remains central, not by symbolic privilege, but because the available conceptual framework does not yet allow for its displacement.

Theology, present in the background, does not dictate the models: God guarantees the order and intelligibility of the world, but does not intervene in the mechanisms described by astronomy. In this sense, al-Tusi inaugurates a critical and reflective cosmology, in which models are evaluated not only for their effectiveness, but for their conceptual legitimacy, indirectly preparing the later reforms of astronomy, up to Copernicus, who would directly inherit some of his constructions.

**Ibn al-Shatir (circa 1304/1375)**

With Ibn al-Shatir, geocentric astronomy reaches one of its most remarkable points of balance, at once rigorous, coherent, and freed

[24] A Tusi couple is a mathematical device in which a small circle rotates inside a larger one whose diameter is twice that of the smaller. Owing to this ratio of diameters, each point on the circumference of the small circle traces a straight-line trajectory during the rotation. (mathhappens.org)

from several artifices inherited from Ptolemy. Employed in Damascus as the timekeeper responsible for ritual prayer times, Ibn al-Shatir situates his work within a learned tradition in which observational precision is inseparable from religious and calendrical requirements.

His major contribution lies in the construction of planetary models entirely devoid of the equant, while preserving excellent predictive accuracy. To achieve this, he profoundly reworks the systems of deferents and epicycles, employing sophisticated geometric combinations, often inspired by the innovations of al-Tusi, but here brought to a higher level of completion. The result is a mathematically coherent geocentrism, strictly adhering to the principle of uniform circular motions, without recourse to fictitious points incompatible with a reasonable physics.

The cosmos remains closed, structured in spheres, with a central Earth chosen as a reference, not as a metaphysical center. Theology intervenes only in the background, as an ultimate guarantee of the order and regularity of the world, without weighing on the mathematical constructions themselves.

What, in retrospect, makes Ibn al-Shatir particularly decisive is the striking formal proximity between some of his planetary models and those that Copernicus would propose two centuries later, based on a simple shift of the center. His work shows that the transition to heliocentrism did not result from a sudden rupture, but from the internal culmination of a long critique of the Ptolemaic model, carried out in the very name of mathematical coherence and the intelligibility of the cosmos.

**Thomas Aquinas (1225/1274)**

For Thomas Aquinas, cosmology takes the form of a masterful synthesis between the Aristotelian legacy and Christian theology, in which the order of the world is both rationally intelligible and metaphysically grounded in God. The cosmos is conceived as finite, closed, and hierarchical, structured in concentric spheres around a central Earth, each corresponding to a degree of increasing ontological perfection.

This organization is not merely descriptive; it is profoundly teleological: each being possesses its own end, inscribed within the

overall order of creation. Aristotle's unmoved mover is fully theologized: it is no longer an abstract principle of motion, but God himself, pure act, first cause, and ultimate end of all things. However, God does not act as a mechanical agent within the sublunary world. He is the cause of being and of order, not of particular motions, which fall under natural secondary causes.

Thomistic cosmology thus rests on a clear articulation between physics, metaphysics, and theology, each having its own domain without possible contradiction. The heavens, incorruptible and regular, are ontologically distinct from the sublunary world, subject to change and contingency, while still participating in the same rational design. The cosmos appears as a relational system strongly structured by hierarchy, in which the central position of the Earth implies no moral or spiritual privilege, humanity not being at the summit of the scale of beings, but at an intermediate point.

This vision confers an exceptional conceptual stability upon the world, explaining its intellectual longevity: it offers a fully ordered universe, readable by reason, yet ultimately grounded in a transcendence that guarantees both the necessity of natural laws and their final orientation.

### Nicolaus Copernicus (1473/1543)

It is with Nicolaus Copernicus that Western cosmology undergoes a decisive conceptual shift with the introduction of a geometric heliocentrism that reorganizes the entire system of the world without yet overturning its fundamental metaphysical frameworks.

By placing the Sun at the center of planetary motions, Copernicus does not primarily seek to revolutionize physics, but to restore a mathematical coherence undermined by the successive refinements of the Ptolemaic system. The Sun becomes the principle of order around which periods and distances are articulated, offering a new intelligibility to the structure of the heavens. The Earth is now a moving body, endowed with a daily rotation and an annual revolution, which simply explains planetary retrogradations and certain apparent inequalities.

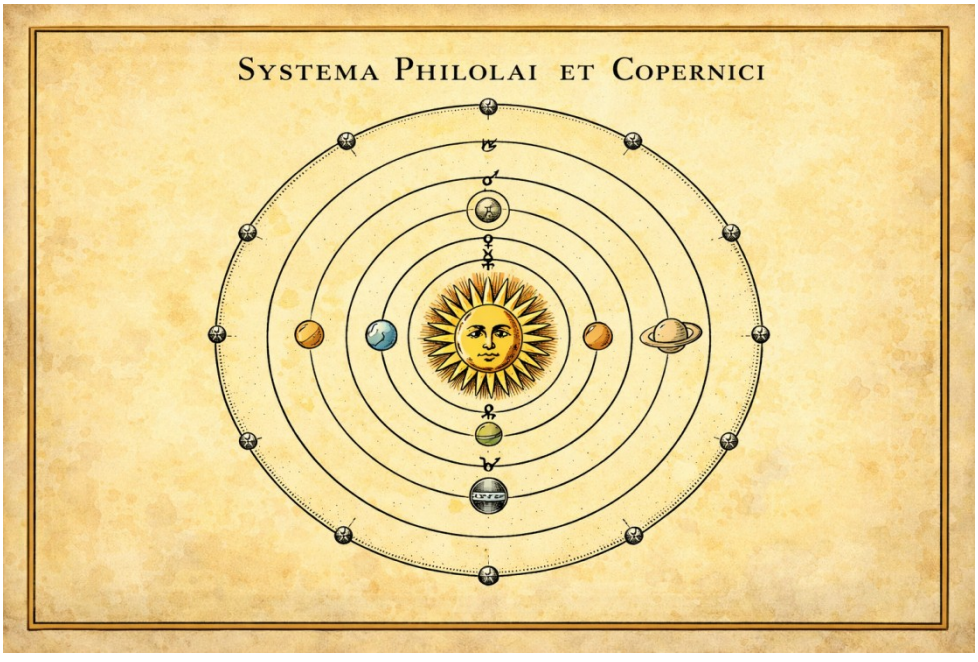


**Figure 7** With Nicolaus Copernicus, the world becomes heliocentric, with all the planets revolving around the Sun, while the stars are relegated to an indefinite beyond.

Yet the Copernican cosmos remains finite, closed, and spherical, bounded by the sphere of the fixed stars, whose immense distance accounts for the absence of observable parallax. Motions remain circular and uniform, and Copernicus retains epicycles, not out of conservatism, but out of fidelity to the geometric principles inherited from Antiquity.

Theology is not directly engaged: God appears in the background as the rational architect of the world, guarantor of the mathematical harmony of the cosmos, but without direct intervention in the mechanisms described. Copernican heliocentrism is therefore not yet an existential or ontological decentering, but a structural reform of the astronomical system, deeply relational, in which the order of the world resides in the geometry of relations rather than in the centrality of the Earth. In this sense, Copernicus opens the way to an irreversible transformation of cosmology, while paradoxically remaining the direct heir of the tradition he helps to surpass.

**Figure 8** Tycho Brahe conceived this strange hybrid sky, with a central Earth and a central Sun as well—but only for the other planets. Ironically, Johannes Kepler, who worked (with difficulty) with Brahe, drew from his data a modern cosmology that moved beyond ancient dogmas.

### Tycho Brahe (1546/1601)

For Tycho Brahe, cosmology at the end of the sixteenth century occupies a pivotal position, at once critical of the classical Ptolemaic model and reluctant toward the physical implications of Copernican heliocentrism. His geo-heliocentric model retains an immobile Earth at the center of the world, around which the Moon and the Sun revolve, while the other planets orbit the latter.

This construction aims to reconcile the geometric elegance of the Copernican system with the physical and observational constraints of the time, notably the absence of measurable stellar parallax, which Tycho considers incompatible with the Earth's annual motion. The cosmos remains closed and spherical, structured by the sphere of the fixed stars, but it is no longer rigid: observations of comets and the supernova of 1572 lead Tycho to reject the existence of solid spheres, opening the way to a fluid and traversable sky.

His approach is deeply empirical: he accumulates data of unmatched precision, without resorting to optical instruments,

establishing a new standard for scientific astronomy. The centrality of the Earth has nothing truly theological for him, but results from a conceptual compromise between Aristotelian tradition and mathematical innovations. God remains in the background as the guarantor of the order of the world, without intervening in the description of celestial motions.

The Tychonic system, often perceived as a transitional solution, is in fact a coherent attempt to preserve a stable relational cosmology while integrating the most advanced observational findings. Paradoxically, it is precisely this framework, deemed conservative, that would provide Kepler with the data necessary to break definitively with perfect circles and usher cosmology into the modern dynamic era.

**Galileo (1564/1642)**

With Galileo, cosmology shifts from a geometrico-metaphysical order to a physically homogeneous universe, grounded in instrument-based observation and experimentation. Through the systematic use of the astronomical telescope, Galileo brings about a radical decentering, not through speculation, but through observed facts: mountains and craters on the Moon, sunspots, the phases of Venus (half lit by the Sun and the other half in darkness, as with the Moon), and the satellites of Jupiter definitively destroy the Aristotelian distinction between a perfect supralunar world and a corruptible sublunar world.

The sky ceases to be an ontologically separate domain. It becomes materially comparable to the Earth, subject to the same irregularities and the same laws. This physical homogenization of the cosmos constitutes a major rupture: the order of the world is no longer guaranteed by the perfection of abstract circles or ideal spheres, but by the measurable regularity of phenomena.

Galileo does not yet provide a complete cosmology in the structural sense, but he destroys its ancient foundations by imposing a new standard of truth, grounded in controlled observation and mathematical language. His adherence to the Copernican system is above all physical and phenomenal: the phases of Venus make geocentrism untenable, independently of any metaphysical consideration. The Earth becomes one body among

others, animated by natural motions, and no longer an exceptional center.

God is not denied, but relegated outside the explanatory field of science: nature is a book written in mathematical language, readable without recourse to theological purpose. With Galileo, the cosmos loses its hierarchical and teleological character to become a continuous, unified space, governed by universal laws, opening the way to a fully physical cosmology in which the intelligibility of the world rests on experience and calculation, and no longer on the authority of tradition.

**Giordano Bruno (1548/1600)**

For Giordano Bruno, cosmology definitively leaves the framework of the closed ancient and medieval world and enters a mode of thought centered on infinity, at once cosmological, metaphysical, and theological. Drawing on Copernican heliocentrism, but radicalizing it, Bruno abolishes the sphere of the fixed stars and rejects any idea of an absolute cosmic center: the universe is infinite, without boundary, without spatial hierarchy, without any ultimate spherical structure.

The stars are no longer lights embedded in a celestial vault, but distant suns, each potentially surrounded by worlds analogous to our own, inhabited or not. This cosmic pluralism dissolves all terrestrial centrality and any cosmological privilege of humankind, in favor of an indefinitely proliferating universe. The disappearance of the spheres also marks the abandonment of a cosmos mechanically ordered by concentric shells. Space becomes homogeneous, open, continuous.

However, this infinity is not that of a modern mathematized physics: it is above all metaphysical. The infinite universe is the direct expression of an infinite divine principle, immanent in the world, and not separate from it. God is no longer external to the cosmos as a transcendent architect, but present in all things as an internal cause and vital principle. Bruno's cosmology is thus deeply relational: each world is a relative center, each point in space equally participates in being.

This vision, philosophically audacious and theologically explosive, far exceeds the available observational data and directly

confronts the doctrinal order of its time. Bruno does not found a scientific astronomy, but he brings about an irreversible conceptual shift: the universe ceases to be a finite structure to be understood and becomes an infinity to be thought, where cosmology becomes inseparable from an ontology of infinity and a radical redefinition of the place of humankind in the world.

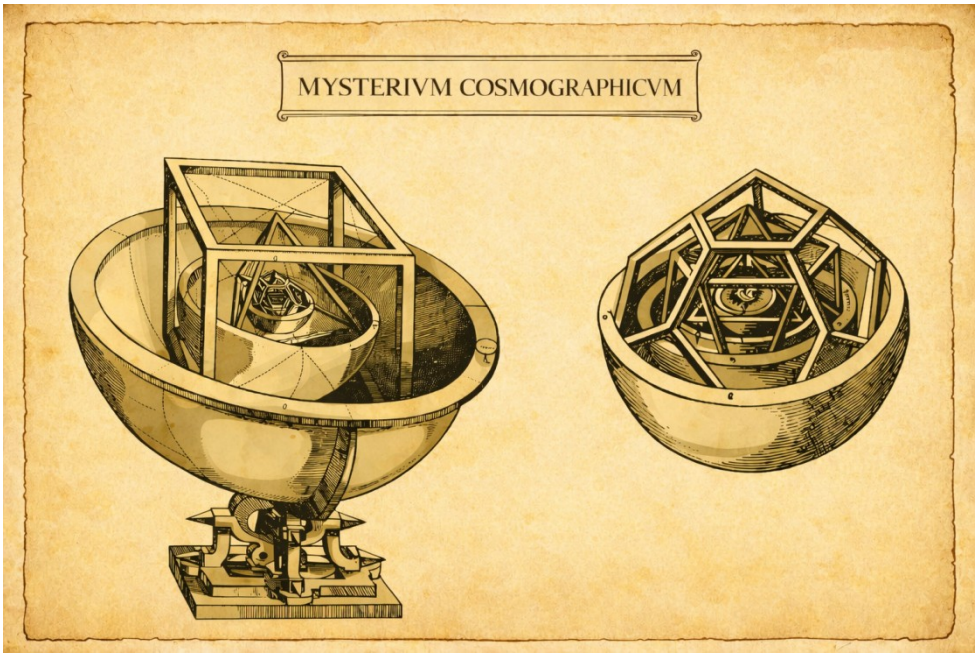


**Figure 9** For Johannes Kepler, the planets trace elliptical orbits around the Sun. Keplerian cosmology is at once mechanistic and teleological, mathematical and spiritual.

### Johannes Kepler (1571/1630)

Johannes Kepler brings modern cosmology across a decisive threshold by explicitly breaking with the ancient ideal of circular perfection in favor of a mathematical order grounded in the reality of phenomena. By establishing that the planets follow elliptical[25] orbits around the Sun, Kepler abandons one of the most deeply rooted dogmas of the cosmological tradition, that of uniform circular motion as the necessary signature of celestial perfection.

[25] An ellipse, in geometry, is the shape one perceives when looking at a circle in perspective, or the figure formed by the shadow of a disk on a flat surface. (Wikipédia)

This break is not a mere technical adjustment: it transforms the very structure of the cosmos, now conceived as a system governed by precise, universal, and constraining mathematical laws. Kepler's three laws describe a world in which velocities vary, distances matter, and the order of the heavens is no longer geometrically ideal, but rigorously calculable.

Yet this cosmos is not devoid of purpose: Kepler remains deeply convinced that the mathematical structure of the world expresses a divine design. The laws are not merely empirical regularities; they are intelligible traces of the harmony willed by God. The Sun, placed at the center, is not just a geometric reference point, but a quasi-motive principle, radiating order and motion.

Keplerian cosmology is thus both mechanistic and teleological, mathematical and spiritual, situated at the interface of two worlds. It marks the definitive end of the closed cosmos of perfect spheres, without yet tipping into a strictly dynamic physics in the Newtonian sense. With Kepler, the heavens become a space of exact quantitative relations, where the intelligibility of the world rests on law rather than form, and where mathematical rationality merges with the reading of a deeply meaningful cosmic order.

**Isaac Newton (1643/1727)**

Finally, with Isaac Newton, cosmology definitively shifts into an infinite, homogeneous universe unified by universal laws, marking the completion of the process of disintegration of the ancient hierarchical cosmos. With the law of universal gravitation and the principles of mechanics, celestial and terrestrial motions now fall under the same explanatory framework: the same laws govern the fall of a stone and the trajectory of the planets.

The celestial spheres disappear definitively, replaced by an infinite, isotropic space without a privileged center, in which bodies interact at a distance. The Newtonian cosmos is no longer ordered by ideal geometric forms or by an internal purpose, but by quantitative dynamic relations, expressible mathematically with unprecedented precision. The universe can be spatially infinite and eternally stable, at least as a first approximation, without the need to assume a closed cosmic architecture.

Theology, in Newton, is present but minimal and external to the explanatory field of physics: God is the creator and ultimate guarantor of order and laws, not their causal competitor. He does not intervene in calculations, but provides the metaphysical grounding for the rationality of the world and for the very existence of absolute space and time. This strict separation between natural laws and theological foundation allows cosmology to become fully scientific, autonomous, and cumulative. The Newtonian cosmos is thus relational in a dynamic sense: it is forces and interactions that structure the universe, not hierarchical positions or essences.

With Newton, an image of the world emerges that is profoundly decentered, in which humankind occupies no particular cosmic place, and where the intelligibility of the universe rests entirely on the stability and universality of laws, opening the way to modern cosmology and all its subsequent developments.

## CONCLUSION

This long journey, from late ancient cosmologies to Newton, reveals a profound transformation in our relationship to the heavens: we move from an interpreted cosmos, laden with symbolic, theological, or metaphysical meaning, to a sky that is progressively objectified, measured, and subjected to procedures of calculation, observation, and verification. We will see that from the Renaissance to the modern era, the heavens cease to be an order to contemplate and become a space to quantify.

Copernicus, Tycho, Galileo, Kepler, and then Newton do not immediately abolish inherited frameworks, but they irreversibly shift the center of gravity of cosmology: intelligibility no longer rests on hierarchy, purpose, or formal perfection, but on the measurable regularity of phenomena. The cosmos gradually becomes a geometric space, then a dynamic one, homogeneous and governed by universal laws, independent of the observer's position.

This transformation directly prepares what will follow in the twentieth century: the idea that the universe is not only structured, but measurable in its extent, its age, its density, and that celestial objects themselves can be classified, compared, and counted. We will see that before Edwin Hubble, the modern sky is already a continuous physical space, yet it remains a cosmos without a truly

reliable cosmic scale, where the Milky Way often remains the ultimate horizon. The "measured sky" before 1920[26], is therefore not a brutal rupture, but the logical outcome of a slow geometrical disenchantment of the world, initiated as early as the Renaissance.

If one attempts a synthetic evaluation of the sizes and shapes of the major cosmologies between the Middle Ages and the Renaissance, one observes an evolution less linear than it may appear, yet highly significant. The medieval Aristotelian-Christian cosmos is finite, closed, spherical, and relatively modest in diameter by modern standards: the sphere of the fixed stars lies at a distance of a few tens of thousands of Earth radii, that is, a still "compact" universe, entirely centered on a spherical Earth, yet conceptually inherited from world maps long limited to the Mediterranean basin and the Old World.

The Renaissance retains this cosmic closure, but the representation of the Earth is transformed: sphericity is fully integrated, the continents expand, and the inclusion of the Americas symbolically enlarges the inhabited world without immediately modifying the size of the cosmos.

With Copernicus and Kepler, the cosmos remains finite and spherical, but it expands considerably: the distance to the fixed stars becomes immense, almost indeterminate, in order to explain the absence of parallax[27]. With Tycho, and then Galileo, the solid spheres disappear, without the universe yet becoming explicitly infinite. Newton, finally, imposes an infinite, homogeneous space without a privileged geometric center, in which the Earth is no longer anything more than one body among others, definitively decentered, both physically and symbolically.

Thus, from the Middle Ages to the modern era, the transition is not simply from a flat Earth to a spherical Earth, nor from a small

[26] 1920 marks the beginning of Edwin Hubble's work, at least through 1930, using the new and more powerful telescope of the time, the 2.5-meter Hooker telescope, installed at Mount Wilson.

[27] Stellar parallax is the apparent change in position of a star against a background of more distant stars. (Wikipedia) On a smaller scale, you can observe a parallax effect by holding your index finger upright at arm's length, aligning it with a nearby object, and alternately closing your right eye and your left eye.

world to a vast universe, but from a centered and hierarchical cosmos to an open, mathematically structured space, where the size of the world ceases to be an essential cosmological datum and becomes an empirical question still largely undetermined on the eve of Hubble.

If one considers the model of Johannes Kepler, the cosmos remains finite, closed, and spherical, even though it is already immensely expanded compared to that of the Middle Ages. The Earth is fully spherical, its size is known with good approximation, and the solar system now possesses a coherent internal scale thanks to the harmonic ratios of the orbits.

In numerical terms, one can propose reasonable orders of magnitude compatible with Keplerian conceptions. The Earth–Sun distance is on the order of 150 million kilometers (1 astronomical unit, even though Kepler does not know its absolute value with precision). The orbit of Saturn, the most distant planet known at the time, lies at about 10 astronomical units, or roughly 1.5 billion kilometers from the Sun. Up to this point, the cosmos remains relatively "compact." But the break occurs with the fixed stars: for Kepler, they must be located at enormous distances, at least several thousand, or even several tens of thousands of astronomical units, so that the Earth's annual motion produces no detectable parallax.

If one translates this into kilometers, a star located at only 10,000 astronomical units already corresponds to about 150 billion kilometers in radius. At 100,000 astronomical units, one reaches 15 trillion kilometers. These figures remain far below the actual stellar distances that will be measured in the nineteenth century, but they represent, for the time, a truly staggering universe. The total diameter of the Keplerian cosmos would thus plausibly lie between 3 trillion and 30 trillion kilometers, or even more according to implicit estimates.

This point is conceptually crucial: for Kepler, the world is still finite, but its size is no longer proportionate to the planetary system nor to human experience. The cosmos becomes a mathematically structured object, yet spatially immense, almost indifferent to the terrestrial scale. One is already dealing with a universe in which finitude no longer has intuitive value, only theoretical significance. It is precisely this tension—between a closed world and one that is practically without measurable bounds—that prepares the

Newtonian shift toward infinity and, later on, the modern question of the true size of the universe, which can only be addressed with the effective measurement of stellar and extragalactic distances.

## Second Part

# THE MEASURED SKY

# 1. The Sidereal Universe

From the Renaissance to the modern era, the cosmos becomes a space to be quantified and, as we have just seen, it becomes a geometric, then dynamic, homogeneous space, governed by universal laws independent of the observer's position.

If one now adopts a strictly Newtonian framework, it is no longer possible to assign a finite size in kilometers, because Newton's universe is explicitly infinite. It has neither boundary, nor sphere of fixed stars, nor any definable cosmic radius. Space is absolute, homogeneous, without a geometric center, and extends indefinitely in all directions. In this sense, any attempt at a global quantification is conceptually excluded from the model.

However, if one adopts a more historical and pragmatic, observational point of view—namely, what a Newtonian scholar of the late seventeenth or eighteenth century could reasonably estimate—one can provide orders of magnitude for the universe that were effectively conceivable or observable at the time. The Earth is spherical, with a radius known to within a few percent (about 6,400 km). The Earth–Sun distance is estimated with increasing precision in the eighteenth century, at around 150 million kilometers. Stellar distances, however, remain beyond reach: the absence of measurable parallax imposes immense minimum distances, with no upper bound. One then speaks of tens of trillions of kilometers, or even far more.

It is important to note that, in Newton's framework, this indeterminacy is not a flaw, but a logical consequence of his model. The infinity of space avoids the need for a global gravitational center and ensures a distribution of stars without generalized cosmic collapse. Newtonian cosmology thus replaces a finite but poorly known size with an assumed absence of size. The cosmos is no longer an object measurable as a whole, but an infinite framework within which only local distances can be evaluated.

It is precisely this situation—paradoxical yet stable—that will persist until the nineteenth century: a mathematically infinite, physically unified universe, but empirically without a global cosmic scale, just before the question of the true size of the universe returns

to the forefront with extragalactic astronomy and, ultimately, Edwin Hubble and his great telescope.

The Newtonian paradox is therefore the following: the universe is infinite in theory, but there are no stars beyond the Milky Way, because the limits of astronomical observation at the time do not allow one to go any further. The distinction between galactic stars (within the Milky Way) and extragalactic objects (outside the Milky Way) simply does not exist. The Milky Way is understood as the entirety of visible stars, a vast cluster or a particular distribution of stars in space, but it is not identified as one galaxy among others.

Newton knows, following Galileo, that the Milky Way is composed of a multitude of stars too faint to be seen individually with the naked eye. The "Galilean" telescopes of the time only suggest that the Milky Way consists of an enormous number of stars, so numerous that they appear to form a continuous fabric. However, the nebulae observed through telescopes are still interpreted ambiguously: either as unresolved star clusters, or as diffuse luminous phenomena within the stellar world. In Newton, there is no notion of "island universes," as in Kant[28], nor the idea that some nebulae might be independent stellar systems comparable to the Milky Way.

That said, Newton conceives of a spatially infinite universe populated by stars distributed without a global center. He even imagines relatively autonomous stellar systems in order to avoid a generalized gravitational collapse. But these systems do not yet correspond to galaxies in the astrophysical sense: they remain groupings of stars within the same continuous cosmic space, without distinct ontological status.

In summary, Newton envisions an infinite universe filled with stars, but not a universe composed of multiple galaxies. All known stars implicitly belong to a single "stellar world," which we now call the Milky Way, without it being recognized as a particular entity among others. The true externalization of nebulae beyond the Milky

[28] As early as 1755, Immanuel Kant put forward the idea of "island universes," referring to autonomous stellar systems analogous to the Milky Way, separated by vast dark expanses. Long ignored, this hypothesis stands as a remarkable conceptual anticipation of the extragalactic cosmology of the twentieth century, formulated long before Edwin Hubble's empirical evidence came to confirm it.

Way, and thus the discovery of other galaxies, will only become possible in the twentieth century, with the measurement of extragalactic distances, long after Newton.

One must acknowledge here the genius of Isaac Newton, capable of going beyond the observational evidence of his time and placing his trust in a theory—universal gravitation—and in calculations that outline a "small" starry sky around the Earth and a space beyond that appears empty and infinite.

For Newton, the observable stellar universe effectively corresponds to what we now call the Milky Way, even if he does not conceptualize it as a distinct galaxy. Thus, the only concretely conceivable distances concern visible stars. The minimum bounds imposed by the absence of parallax lead to stellar distances that are immensely underestimated compared to modern measurements. One is then dealing with orders of magnitude ranging from 1 trillion to 100 trillion kilometers, whereas the Milky Way is now estimated to have a diameter of about 1,000 million billion kilometers. The discrepancy is therefore enormous, spanning several orders of magnitude, even for our own galaxy.

It must be emphasized, however, that this is not an error in the modern scientific sense, but a structural indeterminacy. Newton is not mistaken in a calculation: he is working within a framework in which the measurement of stellar distances is technically impossible and conceptually secondary. The Newtonian universe is infinite in principle, but empirically accessible only through a stellar neighborhood that is extremely poorly scaled.

In summary, before Hubble—and even long after Newton—the "size of the universe" is, *de facto*, conflated with the supposed size of the visible stellar world, that is, a proto–Milky Way that is vastly underestimated. It is only with the recognition of galaxies as autonomous entities, and then with the measurement of their distances, that the universe ceases to be confused with our immediate stellar environment and acquires a true cosmic scale. This is what we will see with Hubble's universe.

From the Renaissance to 1920, with strong instrumental and conceptual continuity from the seventeenth to the nineteenth century, astronomers describe a "stellar" universe composed of celestial bodies. Beginning with that starry sky which we have all been able to contemplate, from childhood, like our distant

prehistoric ancestors, on summer nights—giving us, as we now know, a false impression of infinity and charming illusions: "Mom, look! The Moon is following us!"[29] What, then, does the stellar universe consist of?

**Punctual fixed stars**

In the galactic universe as it appeared from the Renaissance to the end of the nineteenth century, the fundamental element of the sky remained the fixed star: punctual, irreducibly unresolved, even at the highest magnifications available. These stars were perceived as points of light without extension (punctuality), embedded on the celestial sphere and organized into figures inherited from Antiquity—the zodiacal constellations—which structured the reading of the sky far more than any physical consideration.

Their diversity was first approached through brightness: an empirical hierarchy of magnitudes, from first to sixth magnitude, provided a simple yet effective classification, without implying anything about distance or intrinsic size. The near absence of measurable parallax until the nineteenth century reinforced the idea of a globally immobile and equidistant firmament, enclosing the Earth within an immense but closed stellar envelope.

Some observers nevertheless noted differences in hue: reddish, yellowish, or slightly bluish stars—without these chromatic variations leading to any coherent physical interpretation. The whole formed an ordered, stable, almost architectural sky, giving the impression of a homogeneous, regular, and enveloping celestial sphere, within which the Earth naturally occupied a central position, not by theological privilege, but by observational evidence.

**The Milky Way**

For the pre-1920 observer, the Milky Way constitutes the most enigmatic and structuring element of the night sky. Visible to the naked eye as a broad, irregular luminous cloud crossing the celestial sphere along an inclined great circle.

[29] Since the Moon is about 384,000 kilometers from the Earth, the parallax effect, which operates for nearby landscapes, disappears, giving the impression of being followed by the lunar body.

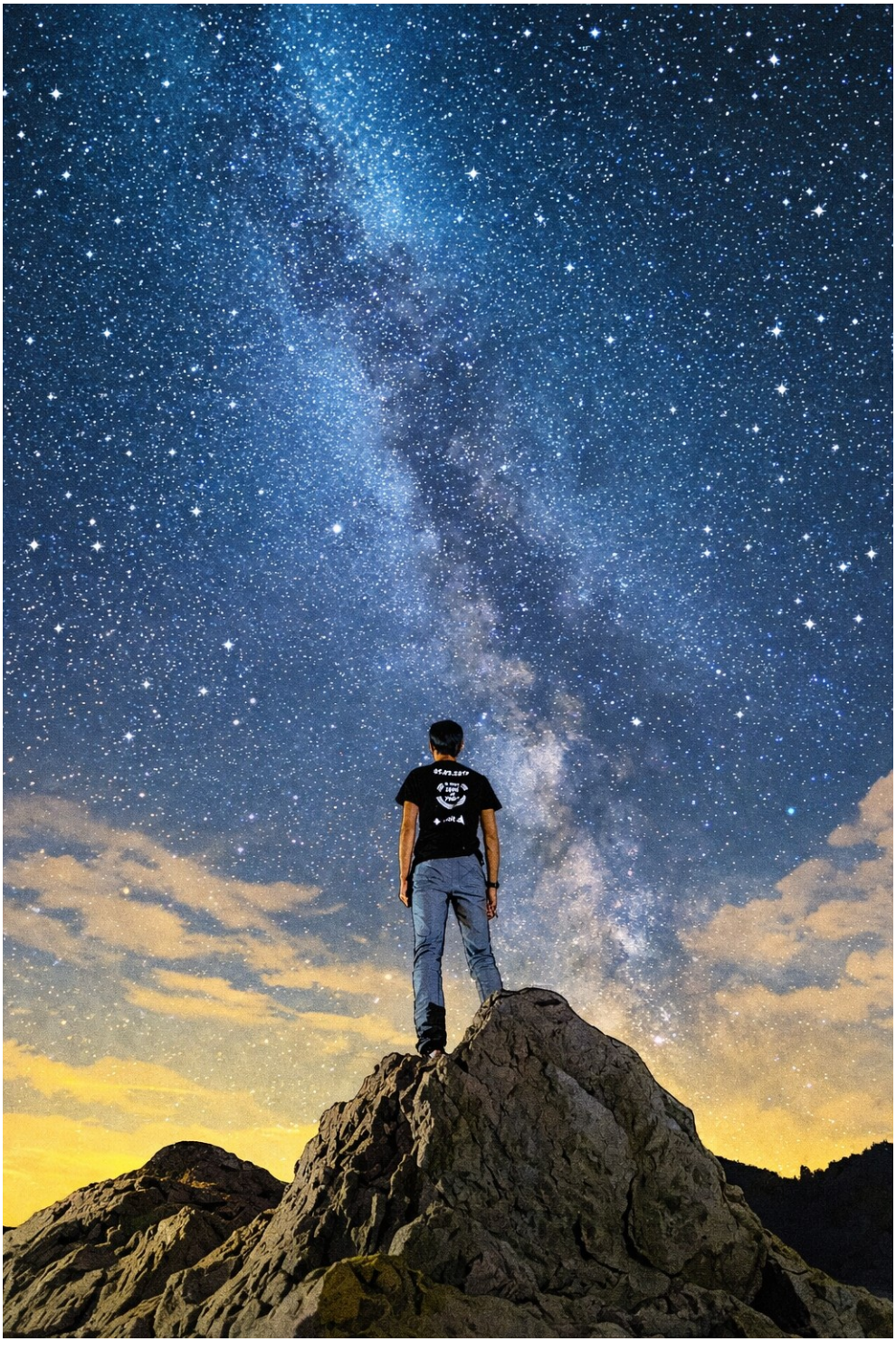

**Figure 10** For Galileo Galilei, this milky glow in the night is understood as an accumulation of innumerable stars: the Milky Way.

It appears neither punctual nor clearly delimited, but diffuse, granular, and sometimes frayed.From Galileo onward, the use of the telescope led to a decisive interpretation: this milky glow was understood as an accumulation of innumerable stars, too faint or too tightly packed to be resolved individually. However, this partial resolution did not dispel the mystery—it deepened it.

The Milky Way displays regions of enhanced brightness, more tenuous areas, and above all dark gaps, perceived alternately as stellar voids or as fissures or absences within the structure of the sky. No clear boundary marks its edges, and no depth can be assigned to it: it appears at once close in its visibility and infinite in its extent.

At the very end of the nineteenth century, the rise of astronomical photography finally made it possible to systematically document the sky of the Southern Hemisphere, until then known mainly through qualitative descriptions. The first plates revealed a Milky Way far brighter, thicker, and more structured than that visible from northern latitudes, particularly in the regions of Sagittarius and Scorpius. This view reinforced the impression of a strong asymmetry in the sidereal sky, with spectacular stellar concentrations and more pronounced dark regions, without however challenging the dominant interpretative framework: it was still a single encompassing galactic system, simply observed from a more favorable angle. These images greatly enriched the description of the sky, yet remained integrated into the Milky Way universe prior to the conceptual break of the nineteen twenties and thirties.

The absence of any perceptible boundary to the Milky Way contributed to the idea of an all-encompassing stellar system, enveloping the Earth without an identifiable center, within which the ordinary starry sky appeared as a mere peripheral thinning. The milky band thus became the visual backbone of the universe, both object and backdrop, without its true spatial status being determined before the twentieth century.

**Open star clusters**

Open star clusters constitute, for the telescopic observer, an intermediate category between the isolated star and diffuse nebulosity. Some, such as the Pleiades or the Hyades, are already visible to the naked eye, but take on a new consistency through the

instrument, revealing themselves as groupings of distinct stars, spatially linked, sometimes tightly packed, sometimes loose.

Other clusters, particularly in Perseus or along the milky band, appear only through the telescope, presenting themselves as partially resolved granular patches whose stellar nature becomes increasingly evident as magnification increases.

These objects pose no major ontological difficulty: they are spontaneously interpreted as local concentrations of stars, unambiguously integrated into the Milky Way. Their preferential distribution along the milky band reinforces the idea of a structured, non-homogeneous stellar system, exhibiting regions of increased density.

These clusters also suggest a diversity of scales in the organization of the sky: the star is no longer merely an isolated unit, but can belong to coherent groupings. Without calling into question the overall image of an enveloping firmament, open clusters introduce a first internal stratification of the galactic sky, composed of nodes, concentrations, and local hierarchies, perceptible well before any dynamic or evolutionary modeling.

**Globular clusters**

Globular clusters occupy a singular place in the sky observed through the telescope, precisely because they long resist a simple interpretation. They appear as circular or slightly elliptical patches, with brightness concentrated toward the center, sometimes granular in appearance, but rarely fully resolved into distinct stars before the use of large nineteenth-century instruments. Their compact morphology clearly distinguishes them from diffuse nebulae, while keeping them at a distance from the punctual star.

A particularly troubling feature for observers is their distribution: many seem to be located outside the visible milky band, where stellar density appears low. This apparent location stands in tension with a strictly galactocentric conception of the sky, in which the Milky Way would constitute the exclusive framework of the stellar system.

**Figure 11** A globular cluster is a very dense grouping of stars, typically containing on the order of a hundred thousand stellar objects. Here, the globular cluster M80.

Should they be seen as peripheral condensations, objects situated at great distances, or structures of another nature? In the absence of parallax and depth markers, the question remains open. Globular clusters thus introduce a discreet but persistent dissonance within the galactic universe: they suggest a more extended and complex architecture than that of a simple luminous disk, without yet providing the observational means to fully conceive this architecture.

**Diffuse nebulae**

Irregular diffuse nebulae appear in observation as blurred luminous expanses, without precise contours, often embedded within the milky band or in its immediate vicinity. Regions such as those of Orion or Carina present themselves as pale clouds, sometimes streaked or unevenly illuminated, whose shape seems to vary depending on the instrument and the observing conditions.

Through the telescope, they do not resolve into distinct stars, or only very marginally, which distinguishes them from both stellar clusters and punctual stars. Their light is perceived as continuous, soft, almost milky, reinforcing the idea of an extended substance rather than a discrete assembly. As a result, they are often interpreted as regions of diffuse matter, even as a kind of cosmic "primitive matter," a luminous fluid intermediate between the star and the void.

Their preferential association with the Milky Way reinforces the idea that they fully belong to the galactic system, with no possible exteriority. These objects thus contribute to a vision of the sky in which space is not empty, but filled with intermediate degrees of luminosity and matter, still poorly differentiated conceptually, and in which the boundary between star, nebulosity, and cosmic medium remains blurred until the end of the nineteenth century.

**Planetary nebulae**

Planetary nebulae, such as the Dumbbell Nebula, first discovered by Messier in 1764, constitute a category very early recognized as distinct in the sky observed through the telescope, due to their singular morphology. They appear as small circular or elliptical disks, of relatively uniform brightness, clearly non-stellar, sometimes surrounded by a more pronounced edge. At low magnification, their appearance evokes that of distant planets, which explains their historical designation, although no proper motion confirms such a kinship.

Some display a greenish or bluish tint, perceptible visually, reinforcing their strange character and their irreducibility to the classical categories of the sky. Unlike diffuse nebulae, they possess relatively sharp contours, and unlike clusters, they do not resolve into stars.

As early as the eighteenth century, this morphological coherence led observers to classify them separately, as a specific family of celestial objects, without their physical nature being understood. Planetary nebulae thus introduce the idea that, within the galactic universe, there exist autonomous luminous forms, neither stellar nor nebular in the broad sense, but belonging to an intermediate category defined first by appearance rather than by origin.

At the end of the nineteenth century, spectroscopic analysis made it possible to establish that planetary nebulae are composed of luminous gas, and not of a stellar continuum. Their discontinuous spectrum indicates emission characteristic of an ionized gas, distinct from that of stars. They were then interpreted as excited gaseous envelopes, associated with a faint or invisible central star. Their small apparent size and high luminosity confirm their local and stellar nature, with no connection to the formation of planetary or galactic systems.

**Figure 12** Not yet recognized as galaxies, the spiral nebulae would come to be identified as such starting in 1920, with the observations and calculations of Edwin Hubble.

### Spiral nebulae

By the end of the nineteenth century, spiral nebulae occupy a deeply ambiguous position in the description of the sky. Observable only with the largest instruments, they appear as disk-shaped or oval objects, displaying an internal structure organized into spiral arms, sometimes emphasized by a granular texture. Objects such as the Andromeda galaxy or the Whirlpool galaxy clearly stand apart from diffuse nebulae through their symmetry and morphological coherence, without however resolving into individual stars.

This visible organization suggests an internal order, yet provides no reliable indication of the distance or true scale of these objects. In the absence of parallax and dynamic markers, their status remains undecidable. Some astronomers interpret them as stellar systems in formation, primordial condensations within the Milky Way. Others regard them as particular structures of the galactic medium, seen from a favorable angle.

The idea that they might constitute autonomous stellar systems comparable to the Milky Way itself is sometimes put forward, but remains marginal and speculative. Thus, within the galactic universe prior to 1920, spiral nebulae represent the point of maximum tension between morphological description and cosmological interpretation: visually rich objects, yet conceptually undecidable, suspended between the internal and the external of the starry sky.

### Double and multiple stars

Double and multiple stars offer, from the earliest telescopic observations, a notable complexification of the sidereal sky. They appear as pairs or small groups of nearby stars, sometimes clearly separated, sometimes almost merged, initially giving rise to the hypothesis of chance alignments on the celestial sphere.

It is only through repeated observations, spread over decades, that certain pairs reveal slow variations in their relative positions, incompatible with a simple visual coincidence. These motions gradually lead to the recognition of physically bound systems, in which stars orbit one another.

This discovery introduces a discreet yet profound conceptual break: the star ceases to be necessarily an isolated, autonomous, and

immobile entity in the firmament. At the local scale, the sky reveals itself to be structured by dynamic relationships, invisible to the naked eye, but accessible through sustained observation.

Double and multiple stars thus suggest that the order of the sky does not lie solely in the apparent geometry of constellations, but also in subtle gravitational architectures, inscribed over time, foreshadowing a more dynamic understanding of the galactic universe.

**Variable stars**

Variable stars introduce, very early on, a conceptual crack in the idea of an immutable sky. Identified through sometimes slow, sometimes rapid variations in their brightness, some become emblematic, such as Mira or Algol, precisely because their behavior contradicts the expected stability of fixed stars.

To the naked eye or through the telescope, these changes in luminosity cannot be attributed to instrumental flaws or atmospheric phenomena, as their regularity or recurrence gradually imposes itself. The sky thus ceases to be a simple static backdrop: it becomes a theater of measurable transformations, inscribed in time.

These variations raise profound questions, long without answers, about the very nature of stars: are they intrinsic pulsations, occultations, transient phenomena? In the absence of adequate physical models, the interpretation remains descriptive, yet the conceptual impact is considerable.

Variable stars impose the idea that time is an integral part of the firmament, that the sky evolves, even on the scale of human generations. They thus contribute to shifting astronomy from a science of position toward a science of change, without yet breaking from the Milky Way as the global and encompassing framework.

**Novae**

Novae, *stellae novae* (“new stars”), constitute decisive events in the history of the observed sky, precisely because they appear where nothing was expected. The sudden emergence of bright stars in 1572, then in 1604, visible to the naked eye for weeks or even months, profoundly disrupts the inherited conception of immutable heavens.

Observed and described with rigor by astronomers such as Tycho Brahe and later Johannes Kepler, these new stars show no measurable parallax, unambiguously attesting to their belonging to the stellar sky rather than to the terrestrial or sublunar atmosphere.

Their brightness sometimes rivals that of the planets before gradually fading away. These phenomena impose the idea that the firmament can undergo sudden and irreversible transformations, independent of any regular orbital motion. They thus deliver a decisive blow to the Aristotelian immutability of the heavens, already weakened, and open the way to a conception of the sky as a domain of real physical processes, capable of arising, evolving, and fading out.

Even though their nature long remains mysterious, these new stars inscribe change and eventfulness at the very heart of the sidereal sky.

**Cometary objects**

Cometary objects occupy a marginal yet persistent position in the description of the sky, precisely because they escape the ordinary categories of the starry heavens. Endowed with a diffuse coma and sometimes a long luminous tail, they traverse the firmament along visibly non-circular, changing, often spectacular trajectories, standing in sharp contrast to the apparent regularity of stars and planets.

In the modern period, their belonging to the distant sky is now recognized: they are no longer considered atmospheric or sublunar phenomena, but part of astronomy proper. However, their erratic behavior, their sudden appearance, and their equally unpredictable disappearance keep them conceptually apart from the “starry sky” in the strict sense. They participate neither in the stable geometry of constellations nor in the permanent architecture of the Milky Way.

Comets thus introduce a transient and intrusive dimension into the sky, like exceptional visitors disturbing the sidereal order without altering its overall structure. They remind us that the visible universe is not limited to a fixed backdrop, but can be traversed by mobile, ephemeral objects whose presence, although recognized as celestial, long remains peripheral in the representation of the galactic universe.

**Figure 13** Comets, with their seemingly mysterious and irregular trajectories, were for a long time regarded by humans as sources of omens, whether auspicious or ill-omened.

### Dark regions of the Milky Way

The dark regions of the Milky Way constitute a paradoxical element of the sidereal sky, all the more striking as they appear at the very heart of the richest stellar region. To the naked eye as well as through the telescope, they present themselves as irregular gaps, depressions, sometimes true fissures cutting through the luminous band, giving the impression of local stellar absences.

Long described in a purely empirical manner, these regions are interpreted either as genuinely empty areas, or as discontinuities in the distribution of stars, or even as fractures of the firmament itself.

Their relative sharpness, contrasting with the surrounding profusion, reinforces the idea of a complex and non-homogeneous structure of the galactic sky. In the absence of an adequate theoretical framework, the hypothesis of an absorbing screen or an intervening dark medium is not yet convincingly formulated. These

obscurities thus remain descriptive anomalies, well known to observers, yet conceptually mute.

They nevertheless contribute to cracking the image of a Milky Way simply constituted by a superposition of stars, suggesting the existence of invisible processes or structures whose reality will only be fully understood at the turn of the twentieth century.

### Stellar anisotropy

The distribution of stars, as revealed by systematic observation of the sky, very early shows a marked anisotropy. Stars are not distributed homogeneously across the celestial sphere: their density increases significantly along the Milky Way and gradually decreases as one moves away from it, down to the polar regions where the sky appears poorer and more sparsely populated.

This asymmetry is perceived empirically well before any quantitative modeling and constitutes a major structural clue. It suggests that the stellar system is neither spherical nor isotropic, but has a flattened shape, comparable to a lens or a disk. However, this geometry remains purely descriptive: no reliable scale can be assigned to it, neither in diameter nor in thickness.

The absence of measurable stellar parallaxes prevents any mapping in depth, and the apparent concentration of stars is interpreted as much as an effect of perspective as a spatial reality. This anisotropy thus feeds the first attempts to model the Milky Way as a structured, oriented system, yet still closed upon itself. It reinforces the idea of a universe organized around a privileged plane, without however allowing its center to be located or its true boundaries to be delineated.

### A stellar system without edge

One of the most disconcerting features of the galactic sky lies in the absence of any observable edge to the stellar system. Despite the methodical attempts at mapping undertaken from the eighteenth century onward, notably by William Herschel, no clear boundary can be discerned in the distribution of stars. Stellar counts do suggest a gradual decrease in density in certain directions, but never a sharp cutoff, never an identifiable frontier between the system and an empty exterior.

This inability to detect an edge leads to cautious models in which the Milky Way is conceived as a finite, flattened system, yet immersed in a dark, indeterminate space without visible structure. The blackness of the sky beyond the stars can be interpreted neither as a real limit nor as a simple absence of observation. It becomes a conceptual background, a silent outside, posited more than described.

This situation sustains a permanent tension between finitude and indeterminacy: the stellar system is assumed to be bounded, yet its boundaries escape all direct observation. The galactic universe thus appears as a world closed by default, not because it reveals its limits, but because no positive exterior has yet manifested itself to observation.

### The black sky

The sidereal sky finally presents itself as a predominantly dark and silent space, where stars, however numerous they may be along the Milky Way, remain separated by vast expanses of darkness. Between the points of light, no continuous background appears, no homogeneous diffuse glow comes to fill the interval: the sky appears as an openwork fabric, made of deep voids punctuated by isolated flashes.

This persistent darkness, despite the apparent abundance of stars, reinforces the idea of an immense and sparsely populated space, in which luminous matter remains localized rather than uniformly distributed. It also supports the intuition of an essentially empty cosmos, in which the Milky Way constitutes a dense exception rather than a norm.

This contrast between local accumulation and global silence contributes to a representation of the world in which immensity prevails over fullness, and in which the night sky, far from being saturated with light, remains dominated by absence—the very condition for the visibility of stars.

## CONCLUSION

This descriptive corpus constitutes precisely the sidereal universe, or pre-1920 Milky Way: a rich, structured stellar system, yet still closed upon itself, in which the vast majority of the observable sky is

interpreted as belonging to a single ensemble, with no clearly identifiable boundary between the internal and the external.

Beyond the Newtonian paradox, often invoked *a posteriori* and presupposing infinity, it must be recalled that the universe actually conceived between the Renaissance and 1920 is not an infinite universe in the physical sense, but a universe endowed with dimensions, even if these remain uncertain. Stellar space is thought of as immense, certainly, but in principle measurable, structured by the distribution of stars and by the Milky Way itself.

Infinity, when it is invoked, refers less to a real extension than to a conceptual limit: a kind of ultimate horizon, sometimes assimilated to an encompassing "sphere," beyond which there is nothing left to describe or observe. Even in Isaac Newton, infinite space is above all a mathematical and metaphysical framework, not a mapped astronomical object.

The observed sky, by contrast, remains finite through its contents, through their gradual rarefaction, and through the absence of any detectable positive exterior. The pre-1920 universe envelops the Earth as a stellar system closed by default, not by dogma, but by descriptive exhaustion. It thus becomes necessary to specify this universe as it is actually conceived: its supposed shape (spherical, lenticular, or discoidal) and, above all, its order of magnitude, expressed in finite distances, in kilometers or in light-years, before the externalization of nebulae comes to shatter this framework.

From the Renaissance to the eighteenth century, the stellar universe is conceived as very vast, yet still relatively compact by modern standards. Since stars are assumed to be comparable to the Sun, their faint brightness implies immense distances; but without any measurable parallax, these distances remain speculative. Reasoning proceeds through lower bounds: if no parallax is detectable, the stars must lie at thousands, then tens of thousands of times the Earth–Sun distance. Distances of 1,000 to 10,000 billion kilometers are commonly proposed for the nearest stars, already placing the universe well beyond the planetary system, yet still within a finite and intelligible order of magnitude. Even if these figures are now largely underestimated, they remain consistent with the idea of a closed stellar universe, possessing a defined size and a determined geometry.

In the nineteenth century, improvements in instrumentation and the emergence of the first stellar parallaxes[30] considerably extend the scale. Nearby stars are now placed at a few light-years, and the most distant visible ones are pushed back to several thousand, even a few tens of thousands of light-years. The Milky Way is then conceived as a stellar disk on the order of 30,000 to 60,000 light-years in diameter, that is, approximately 300,000 to 600,000 billion billion kilometers, surrounded by a dark space without identifiable structure.

Within this framework, infinity is not a space filled with stars stretching endlessly, but an abstract limit, a conceptual beyond of the stellar system. The real universe is the one that contains observable and mappable objects. Beyond that lies only an indeterminate darkness, sometimes conceived as an ultimate envelope, sometimes as a simple cosmic silence. Thus, up to 1920, the universe is indeed thought of as having a finite shape and size, even if its exact boundaries remain unclear. Infinity is not the universe: it is its metaphysical horizon.

Thus closes the Milky Way universe as it is conceived before 1920: an immense yet finite cosmos, structured, hierarchical, in which all visible manifestations—stars, nebulae, clusters—are assumed to belong to a single encompassing system. The uncertainties concern the exact shape, the true scale, the position of the Sun, but not the unity of the stellar universe. Yet this descriptive coherence is already traversed by tensions: asymmetries of the sky, ambiguous objects, undecidable spiral nebulae, peripheral clusters, unexplained obscurities. Nothing yet breaks the framework, but everything weakens it. It is precisely within this in-between—a universe closed by default, yet conceptually fissured—that the “Great Debate” will open: not about abstract infinity, but about the decisive question of whether the visible universe is truly limited to the Milky Way, or whether it is only one system among others, lost within a suddenly multiplied immensity.

[30] Bessel, 1838.

# 2. The Hubble Universe

We had left, at the end of the nineteenth century, a universe still largely indeterminate in its contours, populated by stars and poorly understood nebulae, in which the Milky Way tended to be assimilated to the totality of the cosmos, and in which the hypothesis of other island universes remained speculative, for lack of reliable distances and of an observational framework capable of deciding the matter.

The Great Debate took place on April 26, 1920, in Washington, within the National Academy of Sciences, in a context where observational cosmology was still dominated by stellar astronomy and by major instrumental uncertainties. It primarily opposed Harlow Shapley and Heber Curtis around two related but distinct questions: the actual size of the universe and the nature of the "spiral nebulae."

Shapley, relying on the calibration of Cepheids[31] in globular clusters, defended the idea of an immense Milky Way encompassing the entirety of the known universe, and relegated spiral nebulae to the status of internal or peripheral objects within our galaxy. Curtis, by contrast, argued that the Milky Way was of more modest size and that spiral nebulae were "island universes," independent galaxies located far beyond our own, drawing in particular on the novae observed in Andromeda and on the high radial velocities measured by spectroscopy.

[31] Cepheids are pulsating variable stars whose intrinsic luminosity is simply and monotonically related to their period of variation. This relation was established in the early twentieth century by Henrietta Swan Leavitt, based on her study of the Magellanic Clouds. This period–luminosity relation makes it possible, once the period is measured, to determine the star's absolute magnitude and thus its distance by comparison with its apparent magnitude. Cepheids thus constitute one of the first reliable rungs of the cosmic distance ladder and play a central role in extending the observable universe beyond the Milky Way, at the turn of the nineteen twenties.

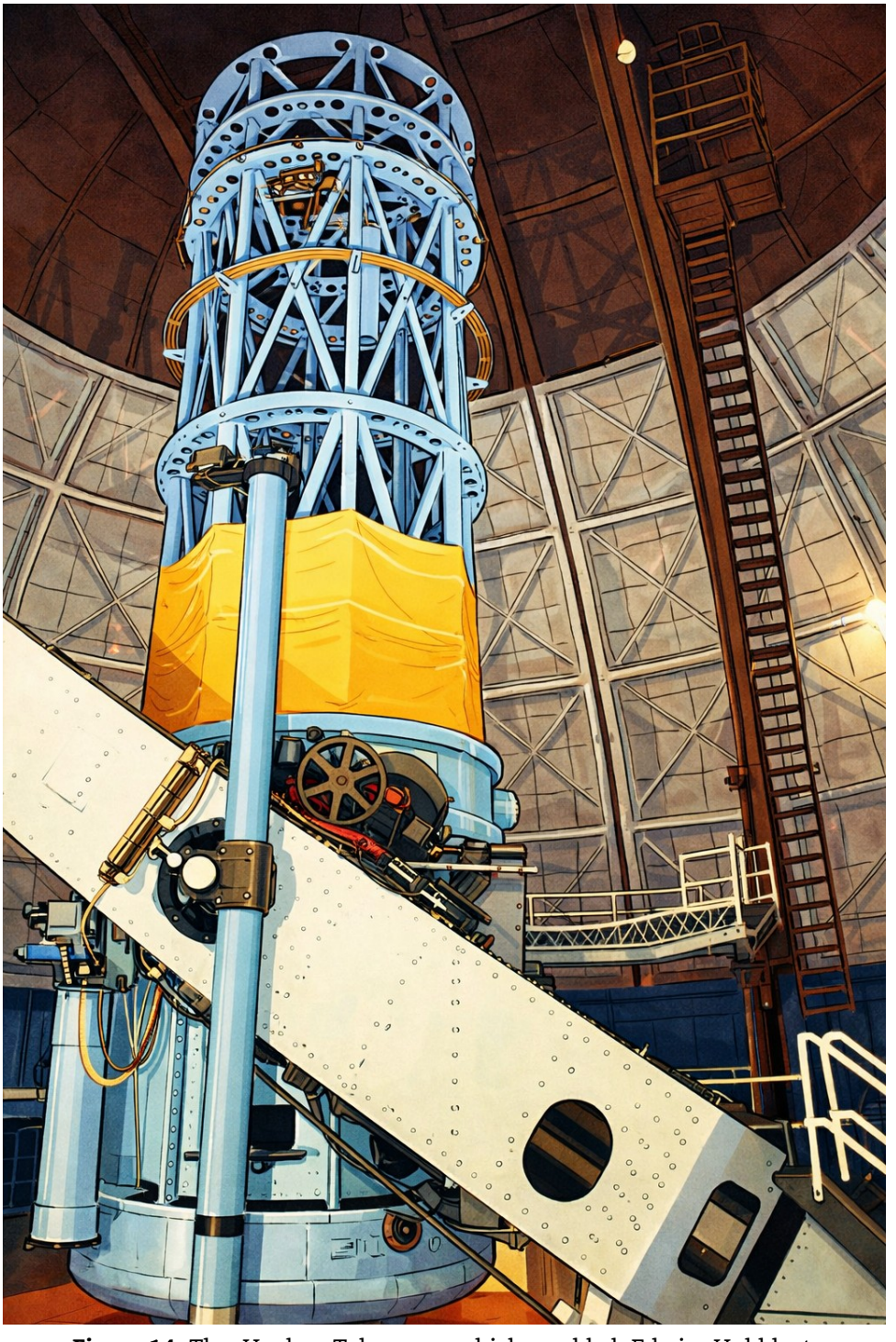

**Figure 14** The Hooker Telescope, which enabled Edwin Hubble to understand nebulae as galaxies and to place them at vast distances from the Milky Way.

The debate does not produce an immediate winner: each is right on certain points and wrong on others, revealing above all the transitional state of knowledge and the methodological limitations of the time. Historically, the Great Debate crystallizes the shift from a galactocentric universe to an extragalactic universe—a shift that will be settled empirically a few years later by the decisive observations of Edwin Hubble, when he establishes unambiguously the external nature of spiral nebulae and opens the way to the universe of galaxies, a conceptual prerequisite for the cosmic expansion of the nineteen twenties and thirties.

**The advent of the Hooker telescope**

At the beginning of the nineteen twenties, astronomy was only just emerging from the Great Debate and remained in a conceptually unstable situation: the observable universe was still regarded, by a significant part of the scientific community, as essentially galactic, centered on a Milky Way whose considerable extent had only just been acknowledged.

Spiral nebulae constituted the most problematic objects: sometimes interpreted as autonomous stellar systems, sometimes as internal structures, or even as secondary phenomena within our galaxy, their status remained ambiguous for lack of reliable distances. Observational tools, however, had just reached a critical threshold with the commissioning of the 2.5-meter Hooker telescope at Mount Wilson. Completed in 1917, it was the largest telescope in the world for more than thirty years and played a major role in the development of modern astrophysics—an instrument that made it possible, for the first time, to resolve individual stars in certain nearby nebulae.

In this context, Cepheids emerged as a decisive metric key: the period–luminosity relation, already established but still poorly calibrated, offered a direct means of moving beyond the mere apparent hierarchy of celestial objects to access a genuine cosmic geometry. The legacy of the Great Debate is therefore less a set of answers than a displacement of the problem: the issue is no longer only to discuss the nature of objects, but to measure the universe, transforming blurred patches and spectra into distances, sizes, and comparable structures. It is in this in-between—where instruments

still outpace stabilized theoretical frameworks—that the Hubble universe opens.

**A decisive observational break**

Between 1923 and 1925, a decisive observational break occurs that effectively brings an end to the framework inherited from the nineteenth century. By exploiting the exceptional resolving power of the Hooker telescope, Edwin Hubble identifies individual Cepheids within the Andromeda nebula (M31), and then in the Triangulum galaxy (M33).

The direct application of the period–luminosity relation leads to distances far exceeding the accepted dimensions of the Milky Way, placing these objects well outside our galaxy. This measurement no longer relies on indirect or statistical argumentation, but on a clear, repeatable metric determination, independent of dynamical models.

The status of spiral nebulae is thus definitively overturned: they are no longer internal or marginal structures, but autonomous stellar systems, comparable to the Milky Way itself. With this demonstration, the model of a universe limited to our galaxy collapses empirically—not through theoretical debate, but through the excess of measured distance. The universe ceases to be a space centered on a single privileged structure and becomes an ensemble populated by multiple galaxies, opening a radical change of scale and concept, an indispensable prerequisite for any modern cosmology.

Before 1923, the Cepheids known and usable as distance indicators were all internal to the Milky Way or, at best, associated with the Magellanic Clouds, whose belonging to the immediate vicinity of the Milky Way posed no conceptual difficulty. They were therefore used to map the internal structure of our galaxy and to estimate its size, notably in the work of Shapley.

With Hubble, for the first time, Cepheids are individually resolved within distant spiral nebulae such as M31 and M33—that is, within stellar systems distinct from the Milky Way. The same metric tool, until then confined to the galactic universe, is suddenly projected onto an extragalactic scale, without any change in method, only through a gain in resolution. It is precisely this instrumental and methodological continuity that makes the demonstration so robust:

Cepheids do not change in nature, but the universe, by contrast, suddenly changes scale.

### Multiple galaxies

The confirmation of the extragalactic nature of spiral nebulae immediately leads to a complete reconfiguration of the observable universe. The Milky Way ceases to be the container of the cosmos and becomes one object among others within a now recognized population of external galaxies, distributed in a space whose extent far exceeds previous estimates.

The first extragalactic distances obtained from Cepheids, although still affected by systematic errors, are sufficient to establish a massive change of scale: the universe accessible to observation is suddenly expanded by a factor between 10 and 100 compared with the models of the early twentieth century. This leap is not merely quantitative, but structural: cosmic space acquires a new depth, hierarchy, and granularity, composed of comparable stellar systems separated by immense voids.

Astronomy thus shifts from an internal mapping of the Milky Way to a topology of extragalactic space, in which distances, sizes, and luminosities become comparable quantities between objects of the same nature. Even if absolute values will later be revised—particularly downward in the case of Hubble's distances—the principle is definitively established: the universe is no longer a single stellar island, but a collection of multiple galaxies, dispersed within a space far more vast than anything the nineteenth century could reasonably conceive.

### Morphological classifications

Once the existence of a population of external galaxies is established, the need arises to describe them, compare them, and organize them according to visible criteria, independently of any causal interpretation.

In the nineteen twenties, Edwin Hubble gradually develops a morphological classification based on the appearance of galaxies, first distinguishing elliptical and spiral forms, then introducing the category of barred spirals. This typology, explicitly intended as descriptive, relies exclusively on simple observational criteria:

degree of concentration, presence or absence of arms, and overall symmetry.

At this stage, it is neither an evolutionary sequence nor a dynamic model of the development of galaxies, but a common language allowing comparison between objects newly recognized as being of the same nature. The "Hubble sequence" thus constitutes a morphological organization, in two branches, of observable galactic diversity.

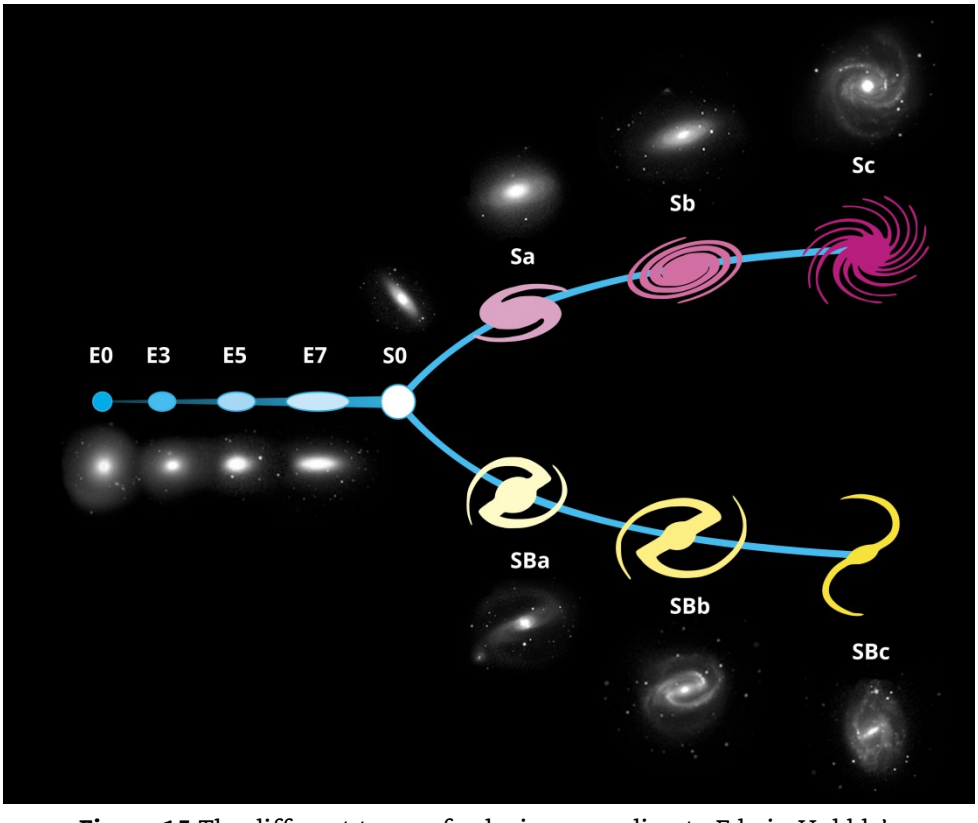


**Figure 15** The different types of galaxies, according to Edwin Hubble's sequence: type E corresponds to an elliptical galaxy, S to a spiral galaxy, and SB to a barred spiral galaxy.

The same applies to the "de Vaucouleurs diagram," which is an explicit and deliberate extension of the Hubble sequence, proposed in the nineteen fifties by Gérard de Vaucouleurs. This diagram introduces a three-branch organization of galactic morphologies, simultaneously incorporating type (elliptical, lenticular, spiral), the presence or absence of a bar, and the degree of opening of spiral

arms. Its structure makes much more explicit the idea of a continuous space of forms, in which transitions are gradual rather than discrete.

Whether in the Hubble sequence or the de Vaucouleurs diagram, these are morphological classifications based on the appearance of galaxies and not evolutionary schemes in the strict sense. Their primary function is to organize the diversity of observed galactic forms using descriptive criteria (global structure, presence of a bar, degree of opening of spiral arms) without positing any temporal trajectory or obligatory direction of transformation. If their organization implicitly suggests possible continuities or transitions between types, such a dynamic reading belongs to later interpretations and not to the original methodological intention, which remains classificatory rather than morphogenetic.

### A global kinematics of the universe

Between 1927 and 1929, a second major shift takes place, this time no longer concerning the structure of the universe, but its overall behavior. Hubble brings into relation the extragalactic distances he has determined with the radial velocities of spiral nebulae, velocities obtained largely thanks to the earlier spectroscopic measurements of Vesto Slipher, who had already, in the nineteen tens, observed very large spectral shifts.

The novelty therefore does not lie in the measurement of the velocities themselves, but in their systematic correlation with distance. By compiling these data, Edwin Hubble reveals an approximately linear relation: the farther a galaxy is, the greater its apparent recession velocity. The result is initially empirical, statistical, and presented with caution, without a fully assumed theoretical framework.

Hubble speaks of apparent velocities and refrains from a strong cosmological interpretation, leaving open the question of their physical meaning. General relativity, although already applied to cosmology by Friedmann and Lemaître, is not yet integrated as the dominant interpretative framework in this observational work.

This moment is crucial: the distance–redshift law[32] is established as a fact, independently of its explanation, and the universe ceases to

[32] Redshift refers to the fact that the light spectrum of a galaxy—that is, the

be only spatially structured, becoming instead a system in which increasing distance is accompanied by a global kinematic behavior.

### Prudence in space

In Hubble's work, the cosmological significance of the distance–redshift relation is approached with remarkable caution, in contrast to later interpretations. He carefully distinguishes between the observational fact (the existence of a correlation between distance and redshift) and its theoretical interpretation, which he initially refuses to fix.

In his publications of the late nineteen twenties, he favors the vocabulary of "apparent velocities," avoiding any explicit assertion of a real expansion of space. This reserve reflects both methodological considerations and a distrust of cosmological models that are still unstable and dependent on general relativity, whose use remains marginal among many observational astronomers at the time.

Hubble is aware of the uncertainties affecting his distance estimates, of selection biases, and of the dispersion of the data, and he refrains from extrapolating beyond what the observations strictly allow. It is therefore not the idea of expansion that he rejects, but its conceptual prematurity. Paradoxically, this restraint strengthens the solidity of his contribution: by rigorously separating measurement from interpretation, Hubble anchors modern cosmology in an empirical foundation independent of theoretical frameworks that are themselves subject to change.

### The Hubble–Lemaître law

The same observational relation—the distance–redshift relation of galaxies—also receives a coherent theoretical interpretation within the framework of general relativity, initially through the work of Friedmann (1922–24). A physicist and mathematician, and a pioneer of modern cosmology, he formulated the first dynamic

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decomposition of its light into colors—is shifted toward the red. This shift indicates that the space between the galaxy and us has expanded during the journey of the light. It gives the appearance of a rapid recession of the galaxy, whereas it is not the object itself that is moving away, but the space it traverses that is stretching.

solutions to Einstein's equations of general relativity, opening the way to the theory of the expansion of the universe.

But it is with Lemaître's studies (1927) that the distance–redshift relation retrospectively acquires a strong cosmological status. In other words, the law is observed by Hubble before being understood as a law of expansion by Lemaître.

Hubble establishes the relation; Lemaître gives it its cosmological meaning, leading to the formulation of a "Hubble–Lemaître" law: the Hubble universe ceases to be merely measured and becomes interpreted.

**Theory and observations converge**

Around 1930, the cosmological landscape is profoundly transformed, to the point that it becomes legitimate to speak of a change in scientific regime. In less than a decade, the galactic universe inherited from the nineteenth century gives way to a universe of multiple galaxies, distributed within a space whose extent and structure are now accessible to measurement.

Cosmology ceases to be a speculative extension of stellar astronomy and becomes a quantitative observational science, grounded in distances, velocities, and empirical correlations. The scale of cosmic distances is established in its principles, even if its numerical values remain approximate, and provides a common framework linking nearby and distant objects within a single measurable geometry.

**Revised extragalactic distances**

In the immediate aftermath of the nineteen twenties and thirties, and without altering the conceptual shift they established, a series of revisions and refinements begin to progressively sharpen the newly revealed universe.

The extragalactic distances determined by Edwin Hubble prove to be affected by systematic errors, particularly due to confusion between different types of Cepheids and to the underestimation of extinction effects, leading to substantial revisions of the cosmic scale in the nineteen thirties and forties.

These corrections have the effect of reducing the value of the Hubble constant, without calling into question the reality of the distance–redshift relation. At the same time, the morphological classification of galaxies is enriched and refined, notably by astronomers such as Walter Baade and later Gérard de Vaucouleurs, who refine the types, introduce continuous transitions, and broaden the initial descriptive framework.

These subsequent developments belong to a process of consolidation rather than refoundation: they correct the figures, densify the categories, and stabilize the tools, but never overturn the fundamental achievement of the years 1923–1929. The transition from a galactic universe to a universe of galaxies, and the entry of cosmology into a metric and observational era, remain definitively established.

## CONCLUSION

At the end of this decisive decade, the universe has changed in nature as much as in scale. A clear transition is observed, from a cosmos still assimilated, at the turn of the nineteenth and twentieth centuries, to a sidereal system dominated by the Milky Way, to a universe populated by multiple galaxies, measurable, comparable, and connected by global kinematic relations.

Edwin Hubble's contribution lies less in having "discovered" expansion in a theoretical sense than in having transformed a sky of ambiguous objects into a structured, metric, and quantifiable space, in which distances and velocities can be correlated independently of any prior cosmology.

The sidereal universe, as it could still be conceived around 1900, corresponds to a Milky Way with a diameter on the order of 100,000 light-years, or about 950 million billion kilometers—already vertiginous on a human scale, yet still finite and centered.

The universe of galaxies, as it emerges between 1923 and 1929, immediately projects observation to distances of several million light-years for the nearest galaxies, corresponding to orders of magnitude between 10 and 100 billion billion kilometers in diameter, and opens, through the distance–redshift relation, a cosmic horizon whose extent is 10 to 100 times greater than that of the previous "Milky Way" sidereal model.

And it is not only the size that explodes, but the very form of the universe, as one passes from a stellar system structured around a center to a space without a privileged center, populated by galaxies in apparent recession relative to one another. In a single decade, astronomy ceases to measure a world and begins to measure the universe.

# 3. The Universe in the Making

**From Galileo to Hubble**

The development of optical instruments, from Galileo's telescope to the Hooker telescope used by Edwin Hubble, corresponds to a gradual expansion of the accessible sky, both through increased light-gathering power and improved measurement precision. Galileo's telescope, at the beginning of the seventeenth century, was a rudimentary instrument, with low magnification and a narrow field of view, composed of a converging lens for the objective and a diverging lens for the eyepiece. It nevertheless enabled a decisive break: lunar mountains, the phases of Venus, the satellites of Jupiter, stellar multiplicity. The sky ceased to be a perfect backdrop and became a structured space, although the instrument remained limited by strong optical aberrations and a very small aperture.

During the seventeenth century, telescopes grew considerably longer in order to reduce chromatic aberrations. Astronomers such as Christiaan Huygens developed more efficient eyepieces and reached extravagant focal lengths, sometimes several tens of meters, at the cost of almost no maneuverability. This phase marks an improvement in angular resolution, but also the intrinsic limits of lens-based instruments. The transition to the reflecting telescope, initiated by Isaac Newton, thus constitutes a major technical turning point: chromatic aberration disappears, and increasing the diameter becomes more feasible.

From the eighteenth to the nineteenth century, reflecting telescopes increase in size and optical quality. William Herschel builds giant instruments for his time, revealing the structure of the Milky Way and the richness of nebulae. At the same time, advances in polishing, silvering of mirrors, and equatorial mounts transform the telescope into a true instrument of celestial mapping. Astronomy gradually ceases to be merely descriptive and becomes statistical and systematic.

William Herschel used and built several major instruments, whose diameters clearly reflect the growing power of optical astronomy at the end of the eighteenth century.

**Figure 16** Galileo Galilei showing his telescope to the Doge of Venice. In broad daylight, with the telescope held horizontally, one wonders what these gentlemen could possibly have been observing…

His first telescopes were modest, around 15 to 20 centimeters in diameter, already sufficient for systematic observations of the sky and for the discovery of Uranus in 1781. He then moved on to more ambitious reflectors, notably a telescope of about 30 centimeters, and then another of 45 centimeters, which allowed him to explore nebulae and star clusters in detail.

His most famous instrument is the "great telescope" at Slough, completed in 1789, equipped with a mirror 1.2 meters in diameter and a focal length of about 12 meters. In its time, it was by far the largest telescope in the world. Although difficult to operate and limited by the quality of its speculum metal mirrors, it marks a symbolic threshold: for the first time, light-gathering power became sufficient to suggest that some nebulae might be distant stellar systems. This diameter would remain unmatched for more than half a century, until the large reflectors of the nineteenth century, and constitutes a direct milestone on the trajectory that leads, a century later, to the 2.5-meter Hooker. From Galileo's telescope to the Hooker, optical instrumentation thus shifted the horizon of the universe, transforming a nearby and finite sky into a deep space populated by innumerable worlds.

**From Hubble to the EELT**

Since the 2.5-meter Hooker Telescope at Mount Wilson, the evolution of ground-based optical instruments has followed a clear trajectory: increasing useful diameter while compensating ever more effectively for the limits imposed by the atmosphere. The Hooker Telescope, commissioned in 1917 at Mount Wilson Observatory, represents the culmination of classical optical design based on a monolithic silvered mirror. For the first time, it combined large aperture, mechanical stability, and spectroscopic instrumentation precise enough to transform astronomy into a science of distances and velocities, paving the way for modern observational cosmology.

The next leap came in 1948 with the 5-meter Hale Telescope at Palomar Observatory. It almost doubled the diameter of the Hooker and ushered in a new technological era: Pyrex mirrors with low thermal expansion, thermal control of the dome, and more rigid mountings. For several decades, the Hale remained the dominant

optical instrument, enabling detailed studies of galaxies, quasars, and the large-scale structure of the Universe.

**Figure 17** Interior view of the European Extremely Large Telescope (EELT – European Extremely Large Telescope).

From the nineteen-seventies and nineteen-eighties onward, a conceptual break emerged with the gradual abandonment of the monolithic mirror in favor of segmented or active solutions. The 3.5- to 4-meter telescopes marked a transitional phase, but it was above all the nineteen-nineties that established the new paradigm with the Keck telescopes at Mauna Kea Observatory. Each of the two instruments has a segmented mirror equivalent to 10 meters in diameter, whose surfaces are continuously adjusted relative to one another by an active optics system. This architecture made it possible to go beyond the mechanical and industrial limits of the solid mirror while preserving excellent image quality.

At the same time, Europe developed an integrated approach with the Very Large Telescope at Cerro Paranal Observatory. Composed of four 8.2-meter telescopes, the VLT illustrates another major development: the interferometric combination of ground-based optical instruments. Without directly increasing the diameter of each individual collector, this approach makes it possible to achieve

angular resolutions equivalent to those of a telescope several tens of meters across, at the cost of considerable instrumental complexity.

Since the beginning of the twenty-first century, adaptive optics has become a central element. By correcting atmospheric turbulence in real time with deformable mirrors and artificial guide stars, ground-based telescopes can achieve, in the visible and near-infrared, resolutions comparable to those of space-based instruments. This advance redefines the role of ground-based astronomy, no longer limited by the atmosphere, but by the technological mastery of its compensation.

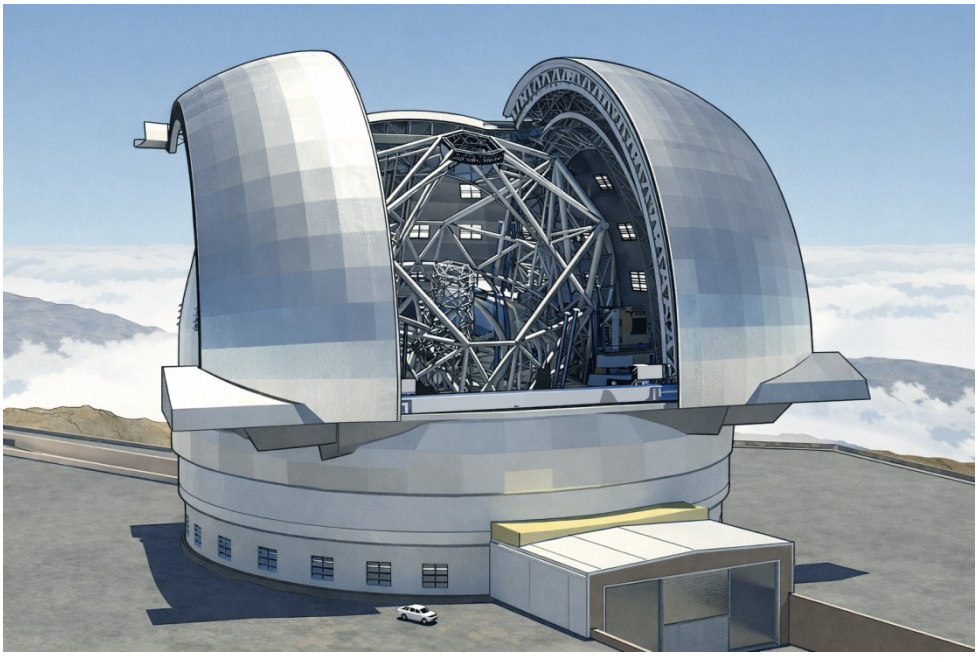

**Figure 18** On-site view of the European Extremely Large Telescope (EELT), built on Cerro Armazones.

Today, this trajectory culminates in the so-called extremely large telescopes, among them the 39-meter European Extremely Large Telescope, now under construction on Cerro Armazones, which directly extends the Hooker–Hale–Keck–VLT lineage. Ground-based optics has therefore not merely grown in size: it has become a complex cybernetic system, in which the collected light is inseparable from its correction, its stabilization, and its real-time processing.

**Beyond the visible**

Beyond optics, ground-based astronomy now explores a large portion of the electromagnetic spectrum, within the limits imposed by the atmosphere. The oldest and most developed of these approaches is radio astronomy, which observes the radio waves and microwaves emitted by the sky. Radio telescopes, whether consisting of single large-diameter antennas or interferometric arrays, make it possible to study cold interstellar gas, pulsars, quasars, active galactic nuclei, and the relic radiation of the Big Bang. Instruments such as those grouped within the Atacama Large Millimeter/submillimeter Array have opened access to millimeter and submillimeter wavelengths, revealing the formation of stars and planetary systems with unprecedented precision.

The millimeter and submillimeter domain occupies a crucial intermediate position between radio waves and infrared. It can be exploited from the ground only at extreme sites, very dry and at high altitude, in order to limit atmospheric absorption. These wavelengths are essential for studying molecular clouds, cold cosmic dust, and the very first phases of cosmic structuring. They complement optical observations by providing access to a Universe largely invisible to the human eye, dominated by diffuse matter and slow thermal processes.

The near and mid-infrared are also accessible from the ground, but only partially. The atmosphere is transparent there only in certain “windows,” and the thermal emission from the ground, the instruments, and the air constitutes a significant background noise. Despite these constraints, ground-based infrared astronomy has become fundamental for the study of star-forming regions, very distant galaxies strongly redshifted, and the atmospheres of exoplanets. Modern large optical telescopes are in fact designed from the outset as integrated optical and infrared instruments.

By contrast, other regions of the spectrum are almost entirely inaccessible from the ground. Ultraviolet radiation is largely absorbed by the atmosphere, as are X-rays and gamma rays, which makes space-based instruments necessary for these wavelengths. Ground-based observations nonetheless contribute indirectly, through detectors of secondary particles produced in the atmosphere or through the observation of indirect effects of high-

energy radiation, notably via atmospheric showers or Cherenkov emissions[33].

Finally, it should be noted that ground-based astronomy is no longer strictly limited to the electromagnetic spectrum. Although already departing from classical optical logic, instruments on the ground now detect non-luminous messengers such as gravitational waves or neutrinos, opening a different relation to the physical Universe. In this broader perspective, ground-based astronomy appears less as a simple alternative to space-based observation than as a coherent set of complementary techniques, each exploiting the windows that the Earth leaves open onto the cosmos.

**Beyond the invisible**

Gravitational waves constitute a form of astronomy that is entirely non-electromagnetic. It is no longer a matter of capturing light, but of detecting the minute distortions of space-time produced by extreme phenomena such as the merger of black holes or neutron stars. These distortions are measured on the ground by giant interferometers, made up of perpendicular arms several kilometers long, in which the phase[34] of two laser beams is compared. Instruments such as LIGO or VIRGO detect variations in length far smaller than the size of a proton. This type of observation does not produce an image of the Universe, but records its vibrations, providing direct access to strong gravitational dynamics, entirely invisible to optical or radio methods.

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[33] Cherenkov emissions are brief flashes of bluish light produced when a charged particle travels through a medium (air or water) at a speed greater than that of light in that medium. In the atmosphere, these flashes are generated by particle showers created by cosmic rays or very high-energy gamma rays. Observing these flashes from the ground allows for the indirect detection of these energetic cosmic phenomena. The effect was first identified by Pavel Cherenkov in the nineteen-thirties.

[34] In interferometry, comparing the phase of two laser beams makes it possible to detect extremely small differences in path length: a phase shift directly corresponds to a variation in the distance traveled. In interferometers, this property is exploited to measure displacements or deformations much smaller than the wavelength of the light used, making it possible to detect extremely subtle physical phenomena, such as gravitational waves.

Neutrinos open another radically different window. These almost massless, very weakly interacting particles pass through ordinary matter with almost no deflection or absorption. Their detection relies on enormous volumes of transparent matter, water or ice, instrumented with sensors sensitive to Cherenkov light produced when a neutrino exceptionally interacts with an atomic nucleus. Observatories such as IceCube, buried in the Antarctic ice, make it possible to trace back to extremely energetic astrophysical sources, including regions opaque to any form of electromagnetic radiation. Neutrinos thus provide information about deep nuclear and hadronic processes, at the heart of supernovae, active galactic nuclei, or environments close to black holes.

Alongside these two major approaches, other contemporary ground-based techniques exist, more discreet but conceptually important. The direct detection of very high-energy cosmic rays relies on networks of ground-based detectors that measure the arrival of showers of secondary particles produced in the atmosphere. Some experiments also search for signatures of dark matter using ultra-sensitive cryogenic detectors, installed underground to shield them from cosmic noise. These devices do not observe the sky in the classical sense, but attempt to record the extremely rare passage of hypothetical particles linked to the invisible structure of the Universe.

Thus, contemporary ground-based astronomy is no longer limited to observing what radiates. It captures what vibrates, what passes through, what collides, and what barely interacts. These techniques, complementary to optical and radio instruments, transform the observable Universe into a set of heterogeneous signals, in which cosmic information no longer passes solely through light.

### Eye in the sky[35]

Space-based instruments arise from a simple and radical constraint: the atmosphere absorbs, blurs, or itself emits a large part of the electromagnetic spectrum. Placing detectors in orbit therefore amounts to removing the atmospheric ceiling, recovering the raw Universe, without terrestrial filtering. The first astronomical satellites, from the nineteen-sixties onward, explored what the

[35] “Eye in the Sky” is a science fiction novel by Philip K. Dick (1976).

ground cannot see: ultraviolet, X-rays, gamma rays. With them, the Universe ceases to be essentially stellar and becomes violent, unstable, energetic.

**Figure 19** The Hubble Space Telescope, the first to leave a profound mark on both science and the collective imagination, extends—nearly seventy years later—the gaze inaugurated by Edwin Hubble onto the vastness of the cosmos.

In the ultraviolet, space instruments reveal hot stars, ionized interstellar medium, and recent star formation processes, largely invisible in optical wavelengths. But it is above all X-rays and gamma rays that transform our view of the cosmos. Observatories such as Chandra X-ray Observatory or Fermi Gamma-ray Space Telescope show a Universe dominated by black holes, pulsars, supernovae, and relativistic jets. The sky becomes transient, explosive, filled with brief but colossal events, entirely absent from classical maps.

Space-based infrared astronomy marks another major shift. Freed from terrestrial thermal radiation, instruments such as the James Webb Space Telescope, the Spitzer Space Telescope, or the Herschel Space Observatory explore the cold and distant Universe. They probe the birth of stars within dust clouds, the formation of planets, but also the earliest galaxies, whose light is stretched into the infrared by

cosmic expansion. Here, space becomes a machine for looking back in cosmic time.

A special case deserves to be highlighted: the study of the cosmic microwave background. With dedicated satellites such as COBE, WMAP, and especially Planck, space astronomy becomes precision cosmology. It is no longer a matter of observing objects, but a global structure, the fossil imprint of the primordial Universe, emitted about 380,000 years after the Big Bang.

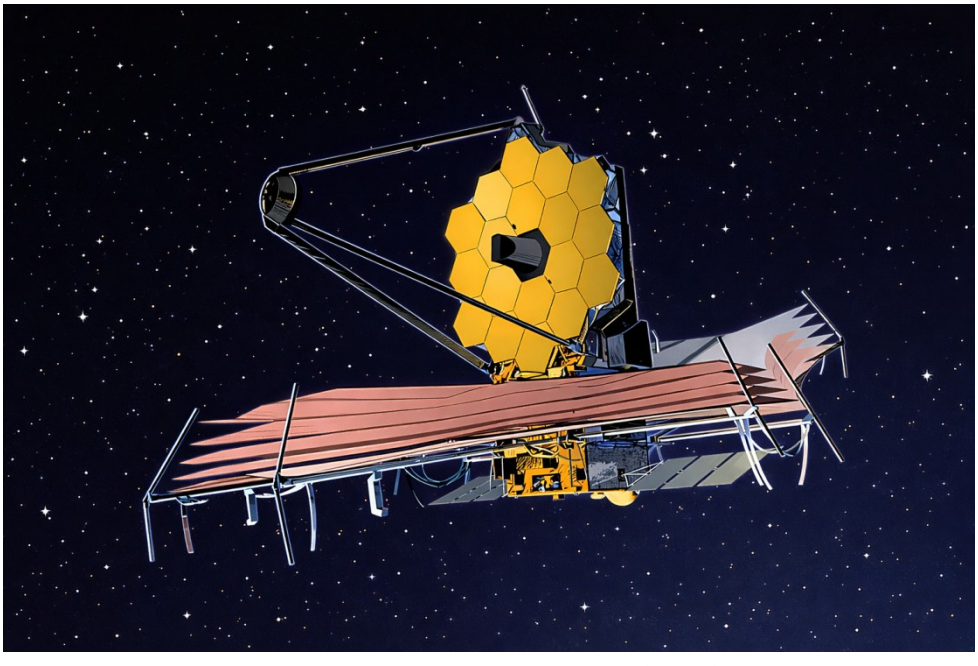

**Figure 20** The James Webb Space Telescope (JWST), deployed 1.5 million kilometers from Earth, captures the infrared light of the first cosmic structures and opens a window onto the beginnings of the Universe.

These missions measure minute anisotropies[36], on the order of a few tens of microkelvins, and determine the fundamental parameters of the cosmological model.

[36] In cosmology, the term “anisotropy” refers to very small spatial variations in a quantity assumed to be globally uniform. In the case of the cosmic microwave background, it refers to tiny differences in temperature and density depending on the direction of observation, remnants of the primordial fluctuations of the young Universe. These anisotropies

Another quiet revolution: space astrometry. Missions such as Gaia seek neither the spectacular nor the exotic, but the systematic and ultra-precise measurement of the positions, distances, and motions of more than a billion stars. The result is not an image, but a six-dimensional[37] dynamic map of the Milky Way. Here, space becomes a tool of galactic geometry, transforming our galaxy into an object measurable in its entirety.

Finally, it should be noted that space-based astronomy is no longer limited to photons. Onboard detectors also observe energetic particles, cosmic rays, and test instruments indirectly related to gravitational waves or fundamental physics. Space thus becomes a laboratory as much as an observatory.

In summary, space-based astronomy does not simply extend ground-based observation: it fragments it into distinct physical states. To each spectral band, to each messenger, corresponds a different Universe. What ground-based astronomy assembles in fragments, space deploys as a complete mosaic, sometimes unsettling, often spectacular, always conceptually destabilizing.

constitute the observed signature of the seeds from which galaxies and large-scale cosmic structures will later form.

[37] The "six dimensions" correspond to the full phase-space coordinates of a star: three dimensions of position (in space) and three dimensions of velocity (components of motion), allowing both its location and its dynamics within the Milky Way to be described.

# 4. The New Sky

From the nineteen-thirties onward, with the work of Hubble, the sky definitively ceases to be a simple inventory of celestial objects and becomes a dynamic physical space, populated by new entities, often invisible to the eye and sometimes even to classical optics. The twentieth century opens a "new sky," not through gradual accumulation, but through successive ruptures, each linked to a major instrumental shift: large telescopes, radio astronomy, space astronomy, particle detectors, interferometry, and then multi-messenger astronomy. As observational windows expand, the very notion of an astronomical object is transformed: we discover not only new bodies, but new physical, energetic, and temporal states. The contemporary sky, as it appears at the beginning of the third millennium, is thus a superposition of heterogeneous layers, ranging from the very cold to the extremely violent, from the almost immobile to the highly transient, from photons to non-luminous messengers.

We will group these new astronomical "objects" and "phenomena" by focusing on the processes, interactions, and signals that feed contemporary cosmology. We have identified six categories to organize and classify these thirty-three "objects" and "phenomena," following a logic of conceptual shift from the most "classical"[38] to the most abstract, in line with the way the sky has expanded in the minds of astronomers since Hubble.

**The dynamic enlargement of space**

This enlargement constitutes the first major rupture of the modern sky. Until the nineteen-twenties, the observable Universe was still largely identified with the Milky Way, perceived as a global stellar system, possibly surrounded by internal nebulae.

[38] "Classical" here referring to what is directly visually observable, stable, localizable, and individuable, and to a sky composed of discrete, durable, and intuitively comprehensible objects.

**Figure 21** Artist's view of the Milky Way and distant galaxies: in projection (top), the whole appears to lie in the same plane, while a change of perspective (bottom) reveals the true depth and the dispersion of galaxies in space.

Within the span of two decades, this framework collapses. The "spiral nebulae" become external galaxies, autonomous, located at staggering distances. This shift is not a simple addition of distant objects: it changes the very scale of astronomical reality. The sky ceases to be a closed and hierarchical space centered on the Earth; it becomes a deep, stratified volume, without a privileged center.

The demonstration of this depth relies on the measurement of extragalactic distances and on the discovery of a systematic relation between distance and spectral shift, synthesized in the work of Edwin Hubble. With this relation, which will become a universal law, the Universe is no longer merely vast; it is dynamic: galaxies move away from one another, not like projectiles in a fixed space, but as markers of a space that is itself expanding. This idea introduces a global cosmic temporality, projecting the Universe into a history, with a past denser and more compact than the present.

Very quickly, attention shifts from individual galaxies to their groupings. Galaxy clusters are identified, bound by their gravity, then superclusters, vast structures whose dimensions exceed anything previously imagined. At these scales, the sky no longer appears as a random distribution of objects, but as a hierarchical organization, composed of filaments, walls, and bubbles, separated by immense voids. What will later be called the large-scale structure begins to emerge, even if its precise contours will only be understood at the end of the twentieth century.

Between the nineteen-thirties and the nineteen-fifties, this first shock thus radically transforms the nature of the sky. Astronomy no longer describes a single world surrounded by secondary objects, but a plurality of worlds, organized in networks, embedded in an expanding space. The transition from a galactic universe to a universe of galaxies is not merely quantitative; it marks the definitive entry of astronomy into modern cosmology, where the ultimate object of description is no longer a local system, but the Universe itself as a global structure.

### Mists in the night

The second change in the nature of the sky concerns the recognition of diffuse matter as a fundamental component of the Universe. As instruments gain in sensitivity and new wavelengths

are exploited, the sky ceases to be interpreted as a collection of isolated point-like objects. It reveals itself to be filled with continuous, structured, evolving media, made of gas and dust, occupying the space between stars and between galaxies. The interstellar medium, long reduced to a simple transparent residue, becomes a full-fledged physical actor, endowed with varying densities, temperatures, chemical compositions, and states of ionization.

This awareness quickly extends beyond galaxies. The intergalactic medium appears as a massive and dynamic component of the Universe, supporting the exchange of matter and energy on large scales. At these diffuse scales, the sky is no longer dominated by well-defined luminous sources, but by gradients, thermal phases (when the Universe passes through successive periods defined by its overall level of heat), and transitions between physical states. Astronomy becomes sensitive to what fills space, and no longer only to what shines within it.

Molecular clouds constitute a nodal point of this new sky. Cold, dense, often opaque in optical wavelengths, they are fully revealed only in radio and infrared. Their study shows that star formation is not a punctual or rare phenomenon, but a continuous process, embedded in the very dynamics of galactic media. Stars are no longer primary entities. They become transient products of the condensation of diffuse matter.

With this transition, the sky acquires a thermodynamic and chemical dimension. It is described in terms of phases of temperature, density, and evolutionary timescales. Cosmic matter is no longer only localized in discrete objects; it circulates, transforms, assembles, and dissociates. This shift marks a profound change in perspective: the Universe is no longer a stage populated by celestial bodies, but an active medium, traversed by continuous physical processes, of which visible objects are only the most condensed manifestations.

**Matter in all its states**

Next comes the diversification of stellar and post-stellar objects, which constitutes another major shift in the modern sky. Variable stars reveal that the apparent stability of the sky is an illusion.

Luminosity and internal structure can oscillate, sometimes regularly, sometimes chaotically. White dwarfs, compact remnants of ordinary stars, introduce the idea of degenerate matter, sustained no longer by nuclear reactions, but by quantum principles.

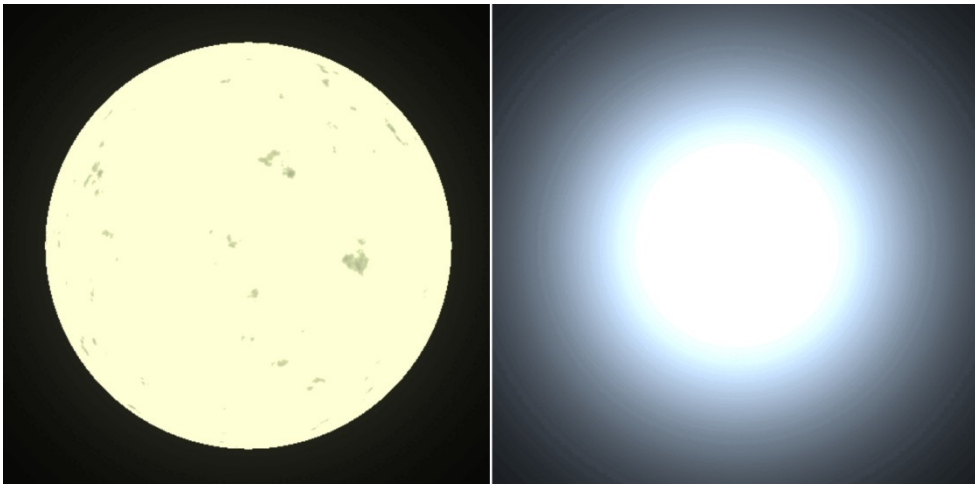

**Figure 22** Representation of the two extreme appearances of a Cepheid (a variable star, giant or supergiant), showing the changes in luminosity and temperature.

With neutron stars, pulsars, and magnetars, the sky enters an extreme regime. Matter is compressed to densities unmatched elsewhere in the observable Universe, gravitational and magnetic fields reach prodigious intensities, and rotation becomes a fundamental parameter. Pulsars, first detected in radio as cosmic beacons of astonishing precision, transform astronomy into a science of time as much as of space. Magnetars, rarer, impose the idea of magnetic fields capable of reshaping the very structure of matter.

Supernovae and their remnants, finally, play a pivotal role. They mark the violent death of certain stars, but also the dissemination of heavy elements into the interstellar medium. They link nuclear physics, stellar dynamics, and the chemical evolution of galaxies. Through them, the end of a star becomes a structuring event on a cosmic scale.

At this stage, the sky is no longer a simple inventory of celestial objects, but a catalogue of possible states of matter, subject to extreme conditions of density, temperature, gravitation, and

magnetic fields. This diversity is fully revealed only through the opening to radio astronomy and to the domains of X-rays and gamma rays, which provide access to a Universe invisible in optical wavelengths, dominated by instability, violence, and continuous transformation.

**The deep structure of space-time**

With compact objects and extreme energetic phenomena, the sky crosses a further threshold: it is no longer a matter of stellar evolution, however violent, but of states dominated by strong gravitation and general relativity. Active galactic nuclei reveal that the core of certain galaxies is the site of phenomena beyond anything found in ordinary stellar physics. A point-like source, more luminous than the entire galaxy that hosts it, imposes the idea that a new mechanism is at work, concentrating energy and matter within an extremely small volume.

Quasars are the most spectacular expression of this. Observed at immense cosmological distances, they testify to intense activity in the young Universe and show that the first galaxies already harbored colossal gravitational engines. Their luminosity, their rapid variability, and their extreme spectral shift move the sky toward scales of power and time previously unimaginable. The Universe becomes not only vast and evolving, but capable of producing continuous energy sources rivaling billions of stars.

Relativistic jets extend this rupture. Emitted perpendicular to accretion disks, they project matter and energy over distances that sometimes exceed the size of galaxies themselves. Their collimation[39], their stability, and their velocities close to that of light impose a fully relativistic interpretation of the observed phenomena. The sky is no longer merely populated by objects; it is traversed by flows, beams, and dynamic structures linking the scales of galactic nuclei to those of the intergalactic medium.

At the heart of this picture stand black holes, along with the compact binaries[40] that constitute their most extreme dynamic

[39] In the astrophysics of relativistic jets, collimation refers to the sustained confinement of the flow over large distances, generally ensured by magnetic fields and the dynamics of the central system.

[40] Compact binaries are stellar systems composed of two compact objects

laboratories. Long regarded as theoretical curiosities, they become central astrophysical objects, both in stellar and supermassive forms. They are not observed directly, but through their gravitational and energetic effects: accretion, X-ray emissions, jets, orbital perturbations. With them, gravitation ceases to be a simple geometric framework; it becomes a direct source of observable phenomena.

In this framework, stellar matter is no longer primary. It is merely a fuel subjected to extreme gravitational fields, where space and time themselves enter into the dynamics. The sky thus definitively shifts toward a relativistic astrophysics, in which understanding objects means understanding the deep structure of space-time.

**The statistical Universe**

The sky changes its nature once again: it ceases to be composed of identifiable objects and becomes a set of global signals and statistical effects. The *cosmic microwave background* pushes this logic to its limit. It does not originate from objects, but from a global state of the early Universe, when it became transparent to radiation. This "background" is neither point-like nor localizable: it is everywhere, isotropic on large scales, and yet carries a fine structure. With it, astronomical observation definitively detaches itself from the idea of discrete sources and becomes the reading of a fossil field.

The anisotropies of this background mark a further conceptual threshold. They are too weak to be perceived as objects, yet too structured to be noise. They are statistical variations, tiny deviations around a dominant uniformity, encoding the primitive history of the Universe. Here, the sky becomes a set of correlations, angular power spectra, and fitted parameters, far more than a map in the classical sense.

Dark matter and dark energy further radicalize this transformation. They are not observed directly, neither by emission nor by absorption. Their presence is inferred from deficits, excesses, and dynamical behaviors incompatible with visible matter alone.

(neutron stars and/or black holes) in close orbit, whose evolution is dominated by relativistic gravitation. They are observed indirectly through their high-energy electromagnetic emissions and, during their inspiral and merger, through gravitational waves.

Rotation curves, gravitational lensing, acceleration of expansion: the sky is now read as much through what is missing as through what is present. Astronomy becomes a science of global gravitational effects.

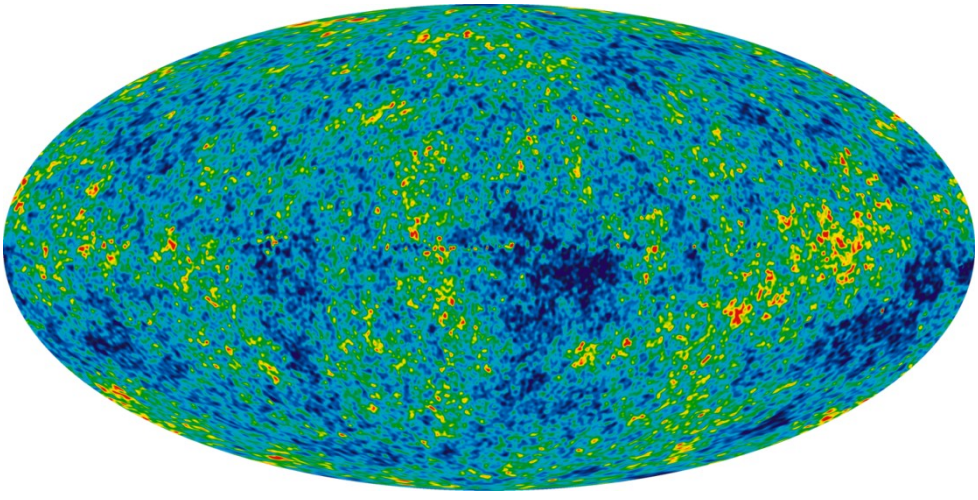

**Figure 23** Full-sky map of the cosmic microwave background (in reality, this background surrounds us like a sphere), reconstructed from images taken by the WMAP space satellite.

At this stage, the sky is no longer a collection of lights, but a physical system reconstructed indirectly. We no longer observe sources, but signatures. There are no longer objects, but distributions; no longer images[41], but statistics. This shift marks the entry into a precision cosmology, where the Universe is approached as a measurable whole, even when its main components remain invisible.

### The contemporary sky

The final change in the nature of the sky corresponds to its present state, where observation is no longer limited to the

[41] I invite the reader to consult this scientific article (Planck Collaboration, 2020), which provides a synthesis of the study of the cosmic microwave background (when the Universe became transparent and luminous, 380 thousand years after the Big Bang) by the Planck space telescope. Not to read its 56 pages or to understand its statistical tables, but to admire its very beautiful "images" (you can download the PDF here: https://bit.ly/4k9102p).

production of images or catalogs, but to the continuous exploitation of heterogeneous data streams. Exoplanets, exoplanetary atmospheres, and protoplanetary disks illustrate an apparent return to more "familiar" objects, but this return is misleading: these objects are not discovered by direct vision, but through indirect signatures—spectral variations, transits, radial velocities, or differential imaging at the limits of instrumental capabilities. The exoplanetary sky becomes a field of statistical analysis, where each system is reconstructed from fragmentary evidence.

Transient phenomena impose another rupture. Gamma-ray bursts, kilonovae[42], fast transients[43] or tidal disruption events[44] cannot be durably mapped. They appear, disappear, and exist as scientific objects only through their real-time detection and their recording. The sky ceases to be a stable picture and becomes a permanent event field, continuously monitored by networks of coordinated instruments.

With gravitational waves and neutrinos, astronomy definitively crosses the boundary of the photon. These messengers produce no image. They deliver temporal signals, correlations, coincidences. Their interpretation relies on synchronization between observatories across the entire surface of the Earth, on the comparison of signatures, and on theoretical modeling. The sky is no longer observed; it is listened to and correlated.

Multi-messenger astronomy synthesizes this transformation. A single astrophysical event can now be apprehended through light, gravitational waves, neutrinos, and sometimes cosmic rays. The object no longer exists within a single channel, but as a convergence of partial signals, distributed in time and across the electromagnetic

[42] An astrophysical classification for events roughly a thousand times (kilo) more energetic than a classical nova, but significantly less than a supernova.

[43] Brief astrophysical phenomena, sometimes lasting from a few milliseconds to a few hours, that appear and disappear without leaving an easily observable persistent source.

[44] Tidal events reveal the presence of massive black holes at the centers of galaxies. They correspond to the partial or total destruction of a star when it approaches too close to the black hole. Tidal forces stretch, then tear apart the ill-fated star. Part of the star's matter is then captured by the black hole, producing a transient luminous flare (in the visible, X-rays, or ultraviolet).

spectrum. The Universe becomes a polyphonic system, whose understanding requires the superposition of distinct readings.

Finally, precision galactic mapping and the exploration of the primordial Universe complete this shift. On the one hand, the Milky Way is reconstructed as a global dynamic system from billions of individual measurements; on the other, the distant primordial Universe is probed down to its earliest observable structures (galaxies at very high redshift). The contemporary sky is no longer a fixed image, but an evolving, multi-scale and multi-messenger database, where knowledge progresses through correlation, accumulation, and integration rather than through simple visual observation.

## CONCLUSION

In the nineteen-thirties, the Universe, as it emerged from the work of Edwin Hubble, remained conceptually simple. It was already immense, populated with external galaxies, and expanding, but its global structure remained largely undetermined. Its curvature, its actual extent, even whether it has a finite size, were unknown. Hubble's Universe was above all a locally observed Universe: a few hundred million light-years at most, without a clearly defined horizon, without a stabilized geometrical model, and without a real distinction between the observable Universe and the total Universe.

Today, in this first quarter of the twenty-first century, the situation is radically different. The observable Universe is defined as the region whose light has had time to reach us since the cosmic origin, which leads to a current size, for this observable Universe, on the order of 93 billion light-years in diameter, that is 880,000 billion billion kilometers[45]. This counterintuitive value results from the expansion of space itself: the regions whose light was emitted about 13.8 billion years ago are now much farther away than they were at the moment of emission. The sky is no longer merely deep; it is bounded by a cosmological horizon[46], a concept absent from the initial Hubblean framework.

[45] To be compared with the "mere" 100 billion billion kilometers of Hubble's Universe in 1930.

[46] The cosmological horizon is a limit beyond which events cannot affect us or be observed, not because the Universe ends, but because light emitted

The global shape of the Universe is also better constrained. Current observations indicate a Universe very close to flat geometry, in the relativistic sense, on large scales. This does not mean that it is necessarily infinite, but that, if it is finite, its radius of curvature far exceeds that of the observable Universe. In other words, even if the Universe has a globally closed topology, it remains beyond observational reach. This distinction between what is measured and what is extrapolated marks a conceptual maturity absent in the nineteen-thirties.

The gap between the Hubblean Universe and the contemporary Universe is therefore not only quantitative, even if it is vertiginous. It is also conceptual. Hubble's Universe is a space that expands. The present Universe is a structured space-time, endowed with an age, a horizon, a thermal history, and possibly an extension far beyond what we can observe. This transition transforms astronomy into cosmology in the strong sense: no longer the description of a content, but the study of a whole, the universal, whose form, size, and limits depend as much on observation as on fundamental physics.

Thousands of researchers around the world thus explore the Universe at a distance. Millions of enthusiasts learn about their results through articles, popular science books, and video documentaries on the internet. Billions are spent to fund all of this, to support theorists, engineers, technicians, to design and build the instruments, and to send them into space. One may then ask the question of the practical outcomes and the benefits this brings to humanity.

In practice, the benefits are tangible, but rarely where they are expected, and almost never in the form of direct applications "planned" in advance. Astronomy and astrophysics are fundamental exploratory sciences, and their practical effects appear mainly as instrumental, methodological, or conceptual derivations, often shifted in time.

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beyond this boundary has not had time to reach us since the beginning of the expansion. This horizon thus marks not a spatial boundary, but a frontier linked to time and to the dynamics of the Universe.

*The 33 objects and phenomena of the sky in the 21st century.*

–External galaxies and galaxy groups
–Galaxy clusters and superclusters
–Cosmic expansion and large-scale structures
–Cosmological redshift
–Interstellar medium and intergalactic medium
–Molecular clouds and star-forming regions
–Variable stars and stellar populations
–Neutron stars
–White dwarfs Neutron stars
–Pulsars
–Magnetars
–Supernovae
–Supernova remnants
–Active galactic nuclei
–Quasars
–Relativistic jets
–Stellar black holes
–Supermassive black holes
–Compact binaries
–Cosmic rays
–Cosmic microwave background
–Anisotropies of the cosmic microwave background
–Dark matter
–Dark energy
–Exoplanets
–Protoplanetary disks
–Exoplanetary atmospheres
–Transient objects
–Gravitational waves
–Astrophysical neutrino sources
–Multi-messenger astronomy
–Dynamic mapping of the Milky Way
–Distant primordial Universe

The first category of benefits concerns instrumentation. Astronomy constantly pushes the limits of detecting weak signals, noise, and spatial and temporal resolution. This has led to major advances in optics, in CCD and CMOS sensors (digital cameras, smartphones, webcams, and video cameras), in cryogenics, in low-temperature electronics, in signal processing, and in imaging. Entire fields of medicine (medical imaging, scanners, MRI, photonic detection), Earth observation, and environmental monitoring now use technologies derived from astronomical developments, sometimes without retaining any memory of their origin.

The second category is computational and statistical. Modern astrophysics works with massive, heterogeneous, incomplete, noisy datasets. Methods of inverse reconstruction, multi-scale correlation, filtering, machine learning, or Bayesian inference have been largely developed or refined in this context. These tools then flow into

finance, climatology, biology, network analysis, or industrial anomaly detection. Here again, the benefit is not an "astronomical result," but a way of thinking and processing information.

There is also a more structural benefit, often underestimated: the mastery of complex systems. Astrophysics requires reasoning about systems that are not experimentally testable, not reproducible, governed by multiple physical states simultaneously (gravitation, plasmas, relativity, turbulence, nuclear processes). This school of thought has deeply influenced critical systems engineering, climate modeling, the management of uncertainty, and decision-making under conditions of partial data.

Finally, there is a cultural and cognitive benefit, less immediately "practical," but historically decisive. Modern cosmology has transformed our relationship to time, space, origin, finitude, and the place of the human being. These transformations indirectly permeate law, ethics, philosophy, education, and even the way societies (modern Western ones) think about the long term.

On a historical scale, this type of benefit is often deeper and more enduring than any isolated technological application. One need only consider the active, and yet very difficult, search for exoplanets in other solar systems, and the pursuit of signs of exobiology (planets located in the temperate orbital zone of their star, the presence of an atmosphere, and chemical markers such as water, oxygen, or methane), which carries, in filigree, the possibility of an intelligence, as is said in fiction, "extraterrestrial"[47].

In summary, astronomy and astrophysics do not produce gadgets; they produce capabilities: seeing the invisible, extracting meaning from noise, reasoning about the inaccessible, and accepting uncertainty as a structuring condition. This may be unspectacular in the short term, but it will, we have no doubt, be extraordinarily fruitful in the long term.

Thus emerges a sky now fully reconstructed, no longer as a simple observable backdrop, but as a set of heterogeneous structures, processes, and physical states, accessible through instrumental and theoretical mediation. This transformation naturally leads to a shift in the question: after identifying the objects, events, and messengers of the Universe, it becomes necessary to examine the very

[47] See Drake, 1961 and Kasting, 1993.

framework within which they are embedded. The next chapter will therefore address the dimensions and geometries of the Universe, not as mathematical abstractions detached from observation, but as the deep conditions that make these phenomena possible, from relativistic space-time to more speculative forms of cosmic architecture.

Part Three

# GEOMETRIES AND SIZES OF THE UNIVERSE

# 1. The Geometries of the Universe

Within the framework of a so-called "standard" cosmology, based on the Big Bang[48], the Universe is considered *homogeneous*, which means identical at every point, with no privileged location, and *isotropic*, which means identical in every direction, with no privileged direction. Of course, all of this is true only "on large scales."

What do we mean by "large scales"? We are no longer at the scale of the galaxy, nor of galaxy clusters, nor even of superclusters of galaxies, nor even of the cosmic web of galaxies (you know, the filaments and walls of galaxies around huge bubbles of empty space...). A "large scale" is something even… larger!

"Large scale" means rather some 1,000 billion billion kilometers. For example, 2,000 or 3,000 or 4,000 billion billion kilometers, depending on the models being considered. It is at such distances that the universe is said to be homogeneous and isotropic. All this is to say that this Universe is described by the Friedmann–Lemaître–Robertson–Walker geometries (FLRW)[49]. Within this framework, three possible spatial geometries are distinguished: (1) closed geometry with positive curvature; (2) flat geometry with zero curvature; and (3) open geometry with negative curvature. All these "geometries" are abstract and very difficult to understand in an intuitive way. Try it, search the internet for anything related to the "hypersphere," headache guaranteed! There is only one solution: to stage it, in order to stimulate the imagination.

**A closed geometry with positive curvature**

This is the geometry of the hypersphere. What is a hypersphere? No, it is not some kind of super-super-sphere with big muscles. It would even, at first glance, be a rather handicapped sphere. If you

[48] We will get to it!

[49] The FLRW model refers to the class of exact solutions of Einstein's equations describing a homogeneous and isotropic universe on "large scales," forming the foundation of the standard cosmological model.

are on an ordinary sphere, say the Earth, you can stand upright. You can walk on it, jump into the air, or dig a hole. But to know whether your space is hyperspherical or something else, your terrestrial means will not be sufficient. Quite simply because you must see the cosmic thing on "large scales"! You must be able to travel, in the blink of an eye, 4,000 billion billion kilometers. And for that, even a Science-Fiction rocket, which would go at the speed of light (I remind you that this is the limiting speed, the one that cannot be exceeded, 1 billion 80 million kilometers per hour), will be of no help to you. Too slow! You must take a Hyper-Science-Fiction rocket, which goes much faster than light.

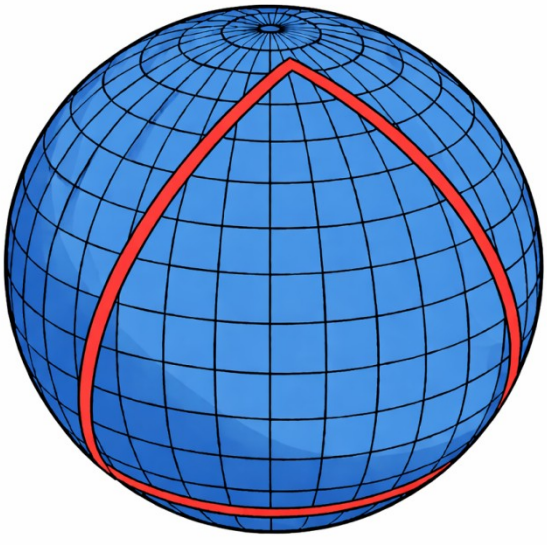

**Figure 24** Spherical model of a closed space with positive curvature.

Well, that cannot exist, we know it, but that is not the point. We are trying to understand, and for that we are going to do what all great scientists do, including Einstein[50]: a thought experiment. Let us therefore imagine a Hyper-Science-Fiction rocket, which can go arbitrarily fast, much faster than light, with no energy limit, no aging (you are quasi-eternal, that goes without saying), without being hindered by the expansion of the Universe. You start from some arbitrary point in space, say the little field next to the house, on

[50] Around the age of sixteen, Albert Einstein mentally envisioned a simple and radical situation: what would one see if one could "ride" a light beam and move at the same speed as it?

the planet Earth that you know well. You choose a direction, say toward the west of the field, and you always move "straight ahead." No turning, no correction, no maneuver. Always straight ahead! Apparently, this is called "following a spatial geodesic." Well, why not.

In a hyperspherical space, this is what happens: at first, absolutely nothing special. For a very long time, everything looks like an ordinary space. Galaxies recede, but there is no sensation of global curvature. Then, at immense distances, far beyond anything we call observable, the trajectory begins to reveal the closure of space. Without ever encountering a wall, without ever turning back, you end up returning from the "opposite side"… and eventually, you reappear at your starting point, from behind. On Earth, in the little field next to the house, you land arriving from the east.

And here comes the vertiginous moment: you have never changed direction, you have never gone around an object, you have never left space. There is no center around which you would have turned. There is no outside. There is no hidden shortcut. It is space itself that is closed. However, even with this Hyper-Science-Fiction rocket, you will not "see" the hypersphere as an object. You will never say "ah, here is the curvature!" You will only observe, after the fact, that your trajectory is closed. The geometry of the Universe does not present itself as a mental image, but as a global property of the path[51].

**A flat geometry with zero curvature**

You are in your Hyper-Science-Fiction rocket. At first, as usual, nothing special. For a very long time, everything looks like an ordinary space. You pass through regions of the Universe that are increasingly distant, galaxies, then regions that are more and more empty. Everything happens as if space were infinite and perfectly mundane. And that is precisely where all the difference lies.

[51] And what about the accelerated expansion of the universe? The geometry may be closed, yet causally inaccessible in its entirety. So? Envision some kind of infinite speed for your Hyper-Science-Fiction rocket? Why not? I'll let you imagine!

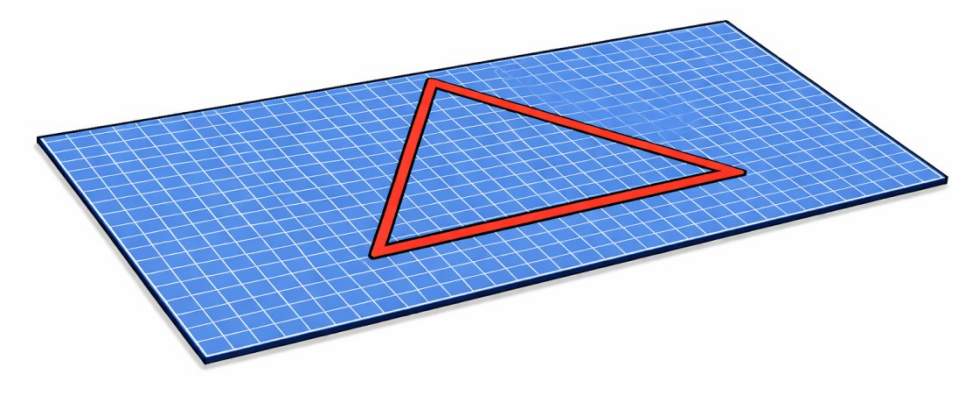

**Figure 25** Flat model of a space with zero curvature.

You can go as fast as you want, for as long as you want, you are never brought back anywhere. You do not loop. You do not unexpectedly return into your own field of view by arriving "from the east." You keep going. Again and again, without end. There is no hidden return, no cosmic shortcut, no closure of space. Space does not fold back onto itself. It has neither edge, nor center, nor any special point. Moving straight ahead means moving away indefinitely. And if you decide to return to your starting point, it is not because space compels you to do so, but only because you have chosen to turn back.

In other words, in a flat geometry with zero curvature, the thought experiment is almost disappointing. The Hyper-Science-Fiction rocket reveals nothing spectacular. It simply confirms this: in a flat geometry with zero curvature, space has no global structure that could manifest itself through an automatic return. It is open, not closed upon itself, and moving "always straight ahead" leads nowhere other than ever farther away. Space simply remains there, the same everywhere, indefinitely.

**An open geometry with negative curvature**

"You are in your Hyper-Science-Fiction rocket. At first, as usual, nothing special. For a very long time, everything looks like an ordinary space. You pass through regions of the Universe that are increasingly distant, galaxies, then regions that are more and more empty. Everything happens as if space were infinite and perfectly mundane..."

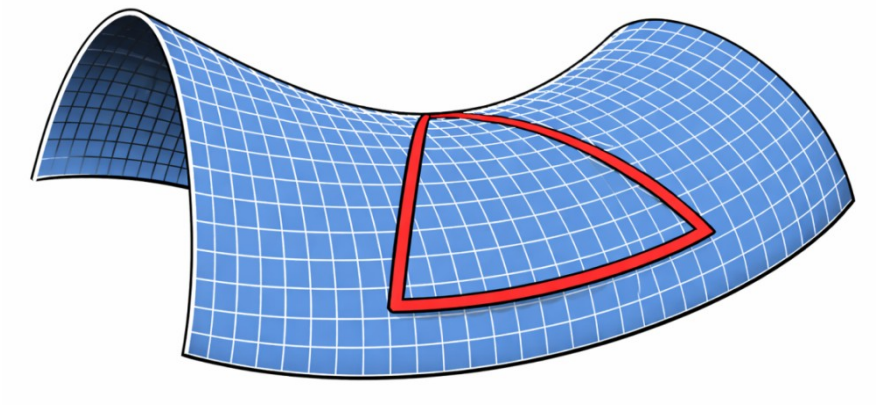

**Figure 26** Hyperbolic model of an open space with negative curvature.

Did you notice? I just copied and pasted the first paragraph that explains "flat geometry with zero curvature." Which means that if you simply stick to your rocket journey, you will see no difference between the "flat with zero curvature" and the "open with negative curvature." You need something else. For example, once your rocket has taken off, you eject two probes that follow your rocket along parallel trajectories, as in a flat space. At first… Because in an open geometry with negative curvature, as you move forward, the distance between the two probes and your rocket increases faster than what flat geometry would predict.

Without acceleration, without force, without external intervention, the trajectories that were initially "parallel" diverge more and more. You do not see space deforming, you do not feel anything locally, but your instruments indicate that distances are growing too quickly. It is not you who are diverging: it is space itself that is opening.

To sum up: in a hyperspherical space, you return to your starting point without intending to; in a flat space, you leave without ever coming back; and in an open space with negative curvature, you leave without ever coming back, but in addition space keeps spreading farther and farther in front of you. All of this, of course, at "large scale," on the order of four thousand trillion trillion kilometers, traveled with a Hyper-Science-Fiction rocket that goes far faster than light.

One thing is certain: these geometries do not tell us whether the Universe is finite or infinite. Current observations of the cosmic

microwave background[52], combined with surveys of large-scale structures, indicate for our Universe a geometry very close to flatness on the observable scale. This means that, within current limits of precision, the global spatial curvature of our Universe is compatible with zero, without excluding an extremely small curvature, positive or negative, at scales far beyond the observable Universe. This near-flatness is naturally interpreted in inflationary scenarios where, just after the Big Bang, a phase of exponential expansion flattened any initial curvature, making space locally indistinguishable from a flat Euclidean space.

**Strange geometries**

Could other geometries have been envisaged for the Universe? The three FLRW geometries (positive, zero, and negative curvature), which we have just seen, are not "all possible geometries," but all those that simultaneously respect the exact homogeneity and isotropy of the Universe on large scales. In other words, they are the result of an extremely strong symmetry choice, and not of any absolute geometrical necessity. As soon as one relaxes these hypotheses even slightly, other cosmological geometries appear.

Very early on, homogeneous but "anisotropic" universes were envisaged, in which space is the same at every point, but not identical in all directions. This is the case for the Bianchi models[53], which constitute a complete classification of the possible

[52] If you remember, it is the famous multicolored image, shaped like a world map, that appeared in the media between 2009 and 2013.

[53] The so-called "Bianchi" cosmological models are based on the classification of homogeneous three-dimensional spaces established by the Italian mathematician Luigi Bianchi at the end of the twentieth century. In his foundational 1898 paper, *Sugli spazi a tre dimensioni che ammettono un gruppo continuo di movimenti* (On three-dimensional spaces that admit a continuous group of motions), Bianchi shows that there exist nine distinct types of possible homogeneous geometries, characterized by their symmetry groups. Applied to general relativity in the twentieth century, these geometries give rise to the Bianchi cosmological models, which generalize the FLRW framework by allowing homogeneous but anisotropic universes. They play an important conceptual role in the study of the primordial Universe and in the analysis of the stability of cosmological isotropy, without being favored by current observations.

homogeneous spatial geometries in general relativity[54]. In these universes, expansion can differ depending on the axis. Space can be "stretched" in one direction and "compressed" in another, without there being any center or edge. These models were studied in particular to understand whether an initially anisotropic universe could evolve toward a quasi-isotropic state like ours. These models are not mathematically exotic, but they greatly complicate the thought experiment of the traveler setting out from his little field, because the very notion of "going straight ahead" becomes dependent on direction.

There are also homogeneous but non-isotropic geometries associated with particular dynamical structures, such as Gödel's universe[55], in which rotating matter induces global rotational effects in spacetime, going so far as to allow, mathematically, closed timelike curves. Here, it is no longer only space that is strange, but causality itself. These models are perfectly consistent in terms of Einstein's equations, but they are ruled out for observational and physical reasons, not geometrical ones.

Other geometries have been envisaged by abandoning even global homogeneity, for example in "lumpy," fractal, or hierarchical universes, where the idea of a single spatial curvature loses its meaning. In these frameworks, geometry is no longer characterized by a simple sign of curvature, but by a multi-scale structure. These are minority approaches, but they have played an important conceptual role, especially in discussions about the validity of the cosmological principle (homogeneity and isotropy on the global scale of the Universe).

Finally, one must distinguish between local geometry and global topology. Even while remaining within a flat geometry, one can have a space that is closed from the topological point of view, by identification of the edges, as in the case of a three-dimensional torus. In that case, the thought experiment of the traveler returning to his little field, "from behind," becomes possible again… without positive curvature. Here again, local geometry is no longer sufficient to characterize the universe: topology is what speaks.

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[54] Ellis et MacCallum, 1969. Wainwright et Ellis, 1997.

[55] Gödel, 1949.

Although many other geometries have been envisaged, the three FLRW geometries are the ones that survive when one imposes maximal symmetry compatible with observations. These three geometries are not "true in essence"; they are simply the most economical from a conceptual point of view. From a scientific point of view, they are the most stable and the most effective for describing the Universe as we observe it today: a practically flat Universe.

**A nearly flat Universe**

Today, the Universe is considered "nearly flat," that is, compatible with a spatial curvature equal to zero within the limits of observational uncertainties. This point is central in contemporary cosmology, not as an aesthetic hypothesis, but as an empirical result arising from several independent observations that converge remarkably.

The main pillar is the study of the cosmic microwave background[56]. The angular anisotropies of this fossil radiation, emitted when the universe was about 380,000 years old, constitute a true geometrical map projected onto the sky. In particular, the angular size of the first oscillations of the primordial plasma provides a cosmological standard ruler. In a geometry with positive curvature, these structures would appear larger than expected; in a geometry with negative curvature, they would appear smaller. Measurements carried out successively by the COBE, WMAP, and Planck satellites show that this size corresponds exactly to what is expected from a Euclidean geometry, therefore flat, on large scales.

This result does not rely solely on the cosmic microwave background. It is reinforced by its combination with other geometrical measurements of the Universe, such as the distance–redshift relation of type Ia [57] supernovae, baryon acoustic

[56] Planck Collaboration (2020).

[57] Read "one-a," where I is the Roman numeral "one" and "a" a sub-classification. Type Ia supernovae are thermonuclear explosions resulting from the destabilization of a white dwarf composed mainly of carbon and oxygen, generally in a binary system, when it reaches a critical mass close to the Chandrasekhar limit (about 1.4 times the mass of the Sun, when electron pressure no longer counterbalances gravity). Their cosmological

oscillations [58] in the distribution of galaxies, and large-scale gravitational lensing measurements. All these observations probe in different ways the relationship between distances, angles (apparent sizes), and expansion, and all converge toward a spatially nearly flat Universe. The robustness of the result comes precisely from this convergence between different observations, and not from a single measurement.

Describing the Universe as "nearly flat" means that the spatial curvature radius, if it is not infinite, is much larger than the observable horizon (the observable Universe). In other words, even if space were very slightly closed or very slightly open, its curvature would be so small that no geometrical experiment feasible on the scale of the observable Universe would be able to detect it directly.

This near-flatness fits naturally within the theoretical framework of cosmic inflation. Inflationary scenarios predict that any initial curvature, whether positive or negative, is rapidly diluted by a very early phase of exponential expansion, making the observable universe almost perfectly flat, whatever its ultimate global geometry. The fact that the universe appears today so close to flat is therefore both an observational confirmation and an indirect argument in favor of inflation, without, however, constituting a unique proof.

Finally, it is important to emphasize a conceptual limitation that is often misunderstood: a locally nearly flat geometry does not necessarily imply a globally infinite universe. As we have specified in

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importance lies in their remarkable intrinsic homogeneity and in the existence of empirical relations that allow their peak luminosity to be standardized. They thus constitute "standard candles" for measuring cosmological distances on large scales. The observation of distant Type Ia supernovae revealed, at the end of the nineteen-nineties, an accelerated expansion of the Universe, implying the existence of a hypothetical dark energy component within the framework of the standard cosmological model.

[58] Baryon acoustic oscillations refer to the fossil imprint, in the spatial distribution of galaxies, of compression waves that propagated through the photon–baryon fluid (protons, neutrons) of the primordial Universe before recombination (the binding of electrons to atomic nuclei). There is thus a direct link between the physics of the primordial plasma and the subsequent structuring of the Universe.

the section on “Strange geometries,” a space can be strictly flat and nevertheless closed from a topological point of view. Current observations strongly support the idea of a nearly zero spatial curvature, which is not the case for global topology. In other words, we know with high confidence that space, on large scales, obeys almost exactly flat Euclidean geometry, but we do not yet know whether it is infinite or finite (space reconnecting with itself) from a topological point of view. This distinction, fundamental on a conceptual level, remains open today.

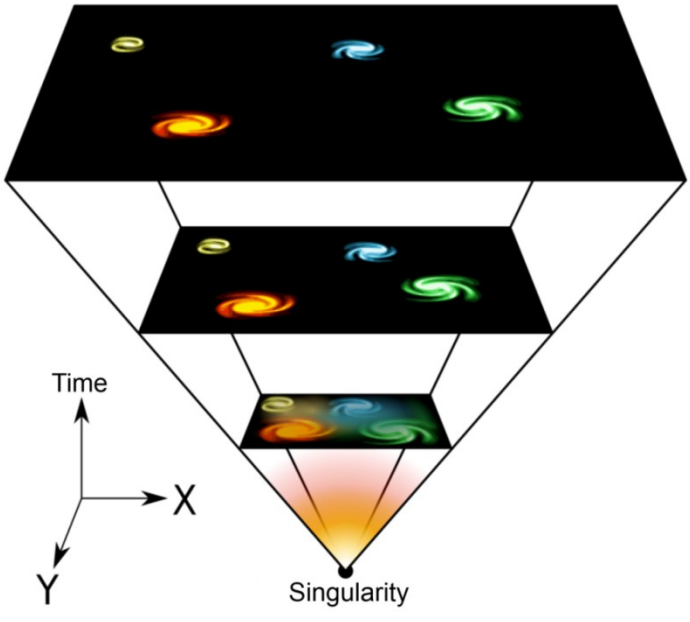


**Figure 27** The Big Bang theory posits that the present Universe emerged from an extremely dense and hot state a little over 13.5 billion years ago, followed by an expansion.

In summary, the nearly flat character of the Universe is neither a convention nor a theoretical preference: it is a solid observational result, arising from the concordance between the cosmic microwave background, the distribution of galaxies, and the dynamics of expansion. But this result, as precise as it may be, leaves intact an essential part of the cosmological vertigo: that of the true size and global structure of the universe beyond the observable horizon.

**The Big Bang universe**

The precursor of the Big Bang model was proposed by Georges Lemaître with his hypothesis of the primeval atom[59]. This model gained credibility with the discovery of fossil radiation by Penzias and Wilson[60], interpreted from a cosmological perspective by Dicke and his collaborators[61], establishing the emergence of the cosmic microwave background in 1965. However, alternatives appeared*: Fred Hoyle, Bondi, and Gold[62] defended the steady-state model, an eternal universe in continuous creation. These visions confronted each other until the nineteen-seventies, when observations of the cosmic microwave background and primordial nucleosynthesis confirmed the expansion and evolution of the universe. The observable universe is about 13.8 billion years old.

The fact that space is now measured as nearly Euclidean, on large scales, does not mean that the Universe is static, nor that it has always exhibited this geometry. This near-flatness is a present geometrical state, observed in the observable Universe, and not an original or timeless property. It must be understood within a dynamic framework, in which the geometry of space is inseparable from the history of its expansion. In other words, the observation of an almost flat space is not a conceptual endpoint, but a strong constraint imposed on any cosmological scenario describing the global evolution of the Universe.

In the contemporary cosmological framework, the Universe is described as originating from an initial state that was extremely dense and hot, followed by a phase of continuous expansion: this is what is referred to as the Big Bang model. It is not an explosion in a preexisting space, but the expansion of space itself, together with the matter and radiation it contains.

As the Universe expands, it cools, successively allowing the formation of particles, atomic nuclei, and then atoms, before the appearance of the first gravitational structures. Observations of the cosmic microwave background, the abundance of light elements,

[59] Lemaître, 1931, 1933.

[60] Penzias et Wilson, 1965.

[61] Dicke, Peebles, Roll et Wilkinson, 1965.

[62] Bondi, Gold et Hoyle, 1948.

and the expansion of galaxies, as measured, constitute the empirical pillars of this model.

Within this framework, the present near-flatness takes on its full meaning: it appears as the result of a prolonged cosmic evolution, potentially amplified by a phase of very rapid expansion in the primordial Universe. The Big Bang therefore does not impose a particular geometry a priori, but provides the dynamic framework in which the almost Euclidean geometry observed today can be understood as a natural state. In any case, understanding the Big Bang requires abandoning the view of a continuous development in favor of the logic of a succession of physical thresholds, each corresponding to a change in effective laws.

At the very beginning of the Universe, there is not yet any "content" in the ordinary sense, but a regime dominated by very high-energy quantum fields. The "quantum fluctuations of the vacuum," amplified by the extremely rapid expansion of space, constitute the seed of all future structures. The inflationary phase, if it did indeed occur[63], not only produces a spectacular expansion, it also imposes remarkably simple initial conditions: near-perfect homogeneity, global isotropy, and very low spatial curvature. At this stage, speaking of particles or gas makes little sense: we are in a regime of fields, not yet of constituted matter.

At the end of inflation, the Universe enters a hot and dense phase dominated by radiation. Elementary particles gradually appear as cooling proceeds: quarks, leptons (electrons), bosons (photons, gluons, W and Z bosons of the weak nuclear interaction, Higgs boson), then there is confinement of quarks into hadrons (protons and neutrons that will constitute atomic nuclei). This is a

[63] The so-called inflationary phase refers to a hypothesis according to which the primordial Universe underwent a very brief period of extremely rapid expansion, prior to the standard hot Big Bang regime. Initially proposed in the early nineteen-eighties, notably by Alan Guth (1981), inflation naturally explains the large-scale homogeneity and isotropy observed, the near-flat geometrical nature of space, as well as the origin of primordial density fluctuations. However, it has not been directly observed: it is inferred from its consequences, and several inflationary models coexist. Inflation thus constitutes a powerful and coherent theoretical framework, largely compatible with current observations, without, to date, being established as a direct empirical fact.

cosmogenesis of matter in the strict sense, governed by the physics of fundamental interactions. When the Universe is a few seconds old, neutrinos decouple. When it is a few minutes old, primordial nucleosynthesis produces light nuclei (essentially hydrogen, helium, and traces of lithium). From that point on, the overall chemical composition of the Universe is largely set.

For hundreds of thousands of years, the Universe remains opaque. Photons constantly scatter off free electrons, and the whole behaves as a single fluid: the photon–baryon plasma (protons and neutrons). It is in this medium that gas-dynamical oscillations develop on cosmological scales. When the Universe reaches about 380,000 years, its expansion and cooling are sufficient to produce recombination: electrons bind to nuclei, neutral atoms form, and photons are suddenly released, leading to the transparency of the universe and the appearance of light[64]. The fossil radiation is then emitted and begins its long journey toward us, forming the cosmic microwave background.

This is followed by a period often called the "dark ages." The Universe is filled with neutral gas, without astrophysical light sources (no stars, no galaxies…), but it is not inactive. Density fluctuations, inherited from earlier phases, grow slowly under the effect of gravity, dominated by the hypothetical "dark matter"[65]. When the first stars ignite, several hundred million years later, they mark the end of this cosmic darkness. Their radiation gradually ionizes the intergalactic medium.

From that point on, the Universe enters the formation of galaxies, galaxy clusters, planets, and heavy elements (such as carbon, iron…). The Universe becomes structured. Expansion continues, at first slowed by gravity. Then, at a relatively recent epoch on the cosmological scale, expansion accelerates under the effect of the hypothetical "dark energy"[66].

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[64] It is still only microwaves, a light that our eyes cannot see.

[65] Dark matter, at the time of writing, remains undetermined and unknown; it is observed only through its effects, via an excess of gravitational influence in galaxies and their clusters.

[66] Dark energy, at the time of writing, remains undetermined and unknown; it is observed only through its effects, via the accelerated expansion of the Universe.

This acceleration is not a new "genesis," but a change in the dynamical regime of expansion itself. It is important to clearly understand that the Big Bang is not a single event, but a continuous history of physical transitions, with, at each stage, different effective laws: quantum fields, relativistic plasma, atomic gas, gravitational structures.

## CONCLUSION

The exploration of the possible geometries of the Universe shows that our understanding of cosmic space has undergone a profound shift, from a purely qualitative intuition to a precise, yet still incomplete, mathematical description. Closed, flat, and open geometries provide a simple conceptual framework for linking curvature, expansion, and cosmic destiny, while the so-called "strange" geometries remind us that local curvature in no way determines global topology.

Contemporary observations converge toward the image of a nearly flat Universe, extraordinarily close to Euclidean geometry on large scales, without however settling the decisive question of its finitude or its infinity. This situation highlights an essential dissociation between what we are able to measure with great precision, the metric geometry of space, and what remains largely undetermined, its global topological structure.

Embedded within the framework of the Big Bang, this geometry is not a static backdrop, but the product of a dynamic history in which expansion, energy content, and initial conditions are intimately linked. The Universe thus appears less as a geometrical object that can be definitively classified than as a structure whose global form remains, in part, an open question of contemporary cosmology.

# 2. The Sizes of the Universe

We are at the beginning of the two-thousands. The Hubble Space Telescope, already crowned with an almost mythical reputation, orbits silently around the Earth, at an altitude of about 570 kilometers. It has already transformed our vision of the cosmos, but a handful of astronomers are entertaining an almost unreasonable idea. What if they dared to do what no one had yet attempted on this scale: point Hubble toward a seemingly empty patch of sky, one of those regions that celestial maps deem uninteresting, and persist. For a long time. A very long time.

The gamble is dizzying. For weeks, then months, the telescope will fix its gaze on a tiny fragment of the southern sky, in the constellation of Fornax. To the naked eye, from Earth, nothing. Not a single bright star. Not a spectacular nebula. An almost perfect black. But this black, astronomers know, is deceptive. It may be precisely there that the deepest history of the Universe is hidden.

Between September 2003 and January 2004, Hubble patiently accumulates light. Not a spectacular snapshot taken on the fly, no. Hundreds of exposures, stacked one upon another, totaling the equivalent of nearly eleven days of continuous observation. Almost one million seconds spent collecting photons that set out billions of years ago, long before the formation of the Sun, long before the Earth, at a time when the Universe was still only a cosmic adolescent.

And then comes the moment of truth. The data are assembled. The image emerges. Where emptiness was expected, there appears an almost obscene profusion of galaxies. Thousands. Elegant spirals, red and aging ellipticals, chaotic galaxies in their infancy, some so distant that their light left their stars less than one billion years after the Big Bang. Each point of light is not a star, but an entire island universe, populated by hundreds of billions of suns.

The shock is immense. This tiny fragment of the sky, no larger than a grain of sand held at arm's length, contains by itself a significant fraction of the observable Universe. The Ultra-Hubble Deep Field[67] does not merely show distant objects, it reveals a

[67] The Ultra-Hubble Deep Field follows the Hubble Deep Field of 1995, itself

temporal depth. To look at this image is to look back, toward the dark ages, toward the time when the first galaxies were assembling, when the Universe was slowly emerging from its primordial night.

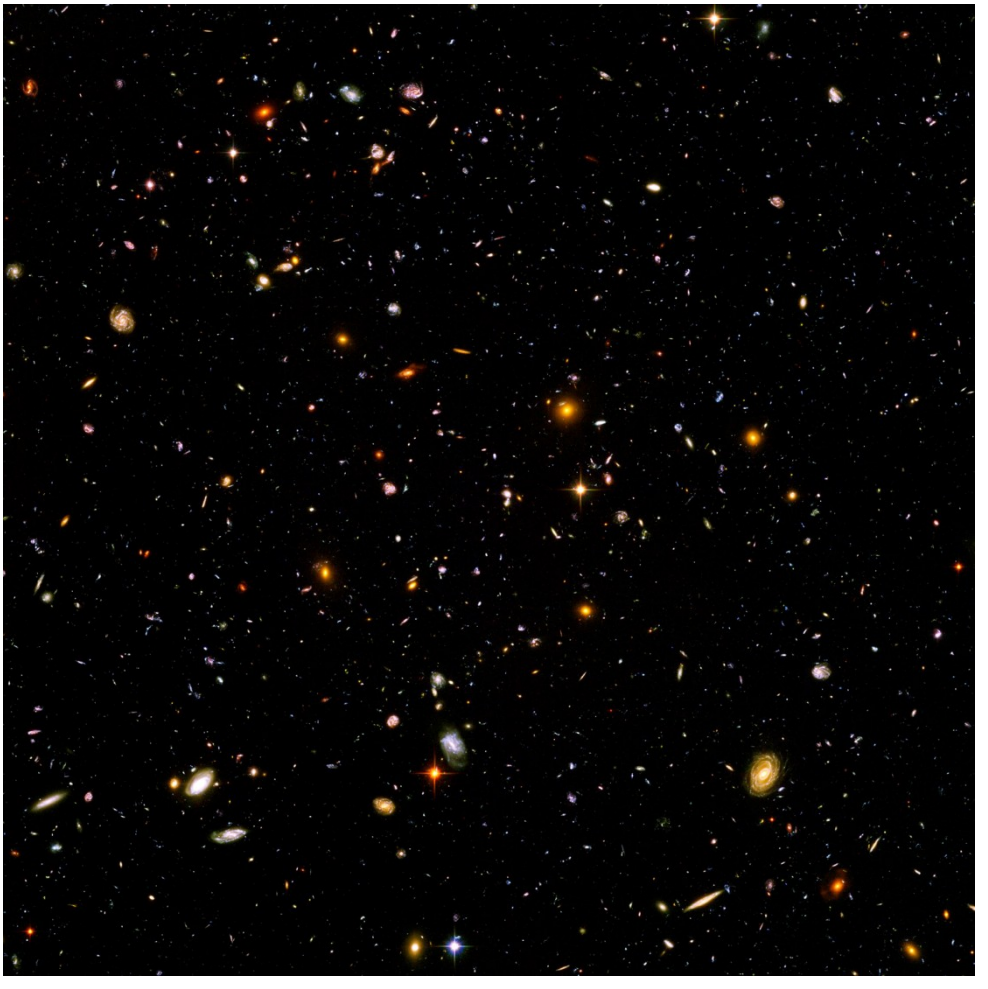

**Figure 28** The famous image from the Hubble Space Telescope containing approximately 10,000 galaxies of varying ages, sizes, shapes, and colors.

But the story does not end there. This image becomes an absolute reference. It confirms that the Universe is filled with galaxies at all epochs, that apparent emptiness is only an illusion tied both to our

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followed by the Hubble Deep Field-South in 1998, to mention only the main "deep fields."

eyes and to our instruments. It also shows that young galaxies are small, irregular, often interacting, as if the cosmos, in its beginnings, were still experimenting with its own forms. This image imposes an almost dizzying idea: wherever one looks, provided one looks long enough, the Universe reveals itself.

The Ultra-Hubble Deep Field is therefore not just a technical feat. It is a cosmic narrative frozen in an image. A story where human patience meets the immensity of time, where a few days of observation reveal thirteen billion years of evolution. An image that whispers, in silence, that even in the darkest corners of the sky, the Universe has never ceased to tell its story.

The images from the Hubble Space Telescope, combined with those of the James Webb Space Telescope, Gaia, and SPHEREx (to mention only the space-based instruments that explore the cosmos as a whole), by revealing that the smallest fragment of the sky contains thousands of galaxies and a dizzying temporal depth, act as a conceptual threshold: from these images onward, the question is no longer only what the Universe contains, but how far it extends, and how, throughout history, human societies have attempted, from two hundred kilometers to infinity, to conceive of and measure its size.

The list of the "sizes of the Universe" is like a historical journey through the different scales of the world, taking into account the orders of magnitude as they were conceivable in each era, even when they were incorrect from the point of view of modern cosmology. The aim is not to retrospectively correct these conceptions, but to restore what "the Universe" could concretely have meant, spatially, for those who conceived it. In other words, it is a matter of following the gradual expansion of the cosmic horizon, not as a simple accumulation of numbers, but as a profound transformation of the human way of inhabiting, conceiving, and situating the world.

This list (next page) tells less a linear progression than a successive collapse of boundaries: from a world on the scale of human territory to a structure whose size, even today, perhaps definitively escapes any closure.

***THE SIZES OF THE UNIVERSE (DIAMETERS)***

| |
|---|
| *Indigenous cosmologies*<br>**200 km**<br>(200 kilometers) |
| *Archaic and classical Greek cosmology*<br>**400 000 000 km**<br>(400 million kilometers) |
| *Ptolemaic cosmology (late Antiquity)*<br>**400 000 000 to 800 000 000 km**<br>(400 to 800 million kilometers) |
| *Medieval Christian cosmology*<br>**1 200 000 000 km**<br>(1.2 billion kilometers) |
| *Copernicus (16th century)*<br>**40 000 000 000 km**<br>(40 billion kilometers) |
| *Kepler (early 17th century)*<br>**200 000 000 000 km**<br>(200 billion kilometers) |
| *Galileo (open stellar universe)*<br>**2 000 000 000 000 km**<br>(2,000 billion kilometers) |
| *Newton (potentially infinite universe, minimum observable)*<br>**200 000 000 000 000 km**<br>(200 trillion kilometers) |
| *Before 1920–1930 (galactic universe)*<br>**2 000 000 000 000 000 000 km**<br>(2 quadrillion kilometers) |
| *1920–1930 (extragalactic universe)*<br>**200 000 000 000 000 000 000 km**<br>(200 quintillion kilometers) |
| *Modern cosmology (observable universe)*<br>**870 000 000 000 000 000 000 000 km**<br>(870 sextillion kilometers) |
| *Total universe (current lower bound)*<br>**≥ 87 000 000 000 000 000 000 000 000 km**<br>(87 septillion kilometers)<br>**∞**<br>(infinite) |

## CONCLUSION

At the end of this third part, after the vertigo of the Ultra-Hubble Deep Field and the layering of the sizes of the Universe, from a few hundred kilometers to infinity, a limit clearly emerges, one that is not that of instruments, but that of knowledge itself. We do not know whether the Universe is finite or infinite. We only know that the observable Universe is finite, by construction, and that any extrapolation beyond it rests on cosmological hypotheses. A Universe can be finite in volume and yet infinite from a topological point of view, without boundary, without exterior, folded back onto itself according to geometries that ordinary intuition struggles to represent. Conversely, it can be spatially infinite, without this ever being directly testable. Numbers, however impressive they may be, therefore do not exhaust the question they seem to raise.

These uncertainties are not weaknesses of the cosmological model, but conceptual points of support. The question of the size of the Universe is not merely a matter of scale or metric; it engages the very structure of reality, its totality, and the way we do or do not accept the idea of a whole that is closed upon itself or without limit. In this sense, speaking of a Universe of so many billions upon billions of kilometers in diameter is never more than a local approximation, a narrative adapted to our position, inscribed within a restricted causal horizon.

These questions take on particular significance as we prepare to take a further step, that of the multiverses. For envisaging a plurality of universes inevitably requires making strong conceptual choices sooner or later. A multiverse of finite worlds is not conceived in the same way as a multiverse of infinite universes.

Can infinite universes coexist without merging into one another? How could finite universes group together, stand side by side, form higher-order structures, or even interact or influence one another? These questions do not yet call for definitive answers, but they do require a framework. It is this framework that must now begin to be constructed, by accepting that between the finite and the infinite, between the singular and the multiple, an essential part of contemporary cosmology is now at stake.

Part Four

# THE MULTIVERSES

# 1. The Block Universe

Before embarking on the path of multiverses, the aim of this section devoted to the block universe is to specify in a concrete and physical way what an elementary "unit" of structure of a multiverse could be, in other words what is meant by a universe. It is a matter of considering it as an entity in its own right, inseparably spatial and temporal, defined, bounded, endowed with a form of closure, even if this closure does not necessarily imply an end in the intuitive sense of the term and may allow for a topological infinity, without boundary or exterior. The issue is therefore not only to speak of extent or duration, but to grasp a coherent whole, a block of spacetime.

From this perspective, the concept of the block universe naturally emerges, derived from relativistic spacetime, which can no longer be avoided once the implications of relativity are taken seriously. It will be necessary to accept representing it, even imperfectly, and to assume its philosophical and metaphysical consequences, in particular the tension it introduces between presentism and eternalism. According to the latter, the block universe is no longer a stage on which time flows, but a totality in which past, present, and future coexist as different regions of a single structure.

Finally, the aim will be to arrive at a definition of the block universe that is neither purely speculative nor exclusively philosophical, but both ontological and physical, situated within an astronomical and astrophysical perspective. It is under this condition that the block universe will be able to play its role as an elementary conceptual building block, an indispensable prerequisite for any rigorous reflection on multiverses.

**Relativistic spacetime**

From the twentieth century onward, modern physics reconstructed the very notion of space and time. With special relativity, Albert Einstein[68] brings about a decisive break: space and time are no longer two independent, universal, and absolute entities,

[68] Einstein, 1905, 1915, 1963. Einstein, Infeld, 1983.

but the components of a single unified structure, spacetime. Events are no longer located "in space at a given instant," but described by their coordinates in a four-dimensional continuum, where measurements of distance and duration depend on the state of motion of the observer. There is no longer any absolute simultaneity: what is present for one observer may belong to the past or the future for another. This relativity of simultaneity already contains, in germ, a profound challenge to the idea of a universal present flowing identically for all.

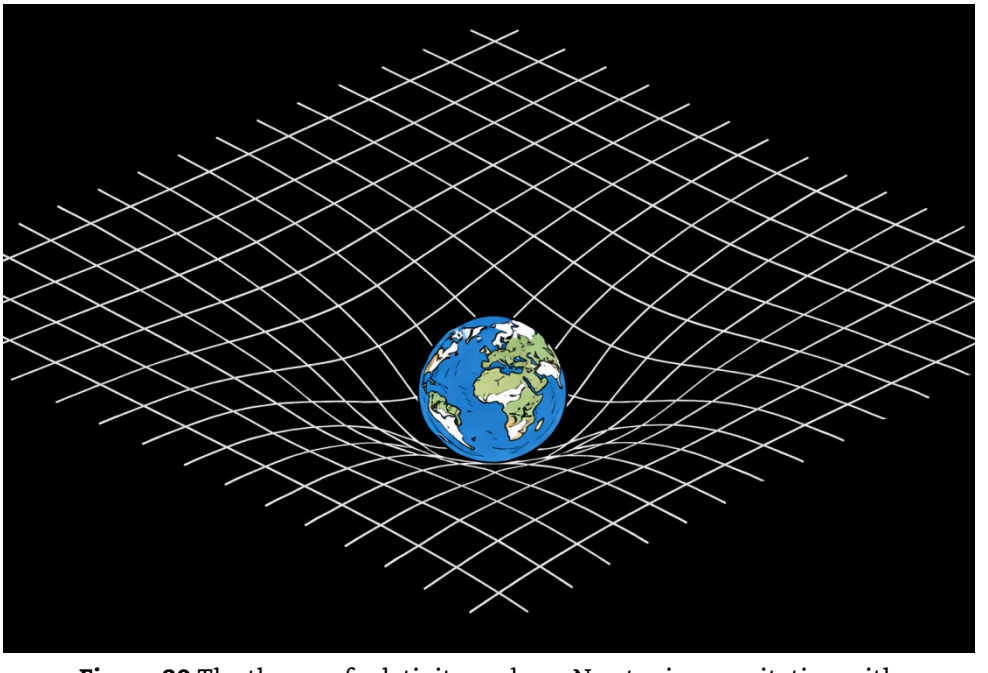

**Figure 29** The theory of relativity replaces Newtonian gravitation with a curvature of spacetime, along which bodies follow geodesics in their motion.

General relativity extends this unification by incorporating gravitation. Spacetime is no longer a simple passive framework in which events unfold, but becomes a dynamic entity whose geometry is shaped by matter and energy. The trajectories of bodies are no longer motions within a given space, but geodesics of spacetime itself. This point is crucial: the history of the Universe is not a sequence of successive states added one to another, but a global structure in which each event has a defined place within the total geometry. In this framework, speaking of a global "becoming" of the

Universe no longer has fundamental meaning; only the variation of proper time along worldlines remains.

It is interesting to note that this geometrical vision does not arise *ex nihilo* with Einstein. Already in Isaac Newton, space and time form a framework with four parameters in which the trajectories of bodies are entirely determined by the laws of motion. Admittedly, space and time are there absolute and separate, but the essential idea is already present: if one knows the initial conditions and the laws, the entire history of the system is, in principle, given as a whole. One can thus reconstruct a complete trajectory in a Newtonian spacetime, even if it is not yet geometrized in the relativistic sense. From this point of view, the conceptual seed of the block universe is already present in classical determinism.

What relativity changes is therefore not only the metric or the dynamics, but the ontological status of time. By unifying space and time into a single geometrical structure, relativity makes natural the idea that past, present, and future are not realities that appear or disappear, but distinct regions of the same spacetime. The block universe is not a marginal or metaphysical interpretation added after the fact: it is the most direct reading of what a relativistic spacetime physically means. It is on this basis that the concept of the block universe takes on its full meaning.

**Representing the block universe**

If, according to relativity, the block universe is an undeniable physical reality, it raises the problem of its concrete, geometrical representation. It is an object with four real dimensions, three of space and one of time, and not an ordinary space "in which things happen." Yet our perceptual system and our cognitive tools for visualization are irreducibly three-dimensional. Thus, any attempt at representation imposes a reduction in the number of dimensions.

The most common reduction consists in sacrificing one spatial dimension, in order to make time appear as an explicit axis, which leads to Minkowski-type[69] spacetime diagrams, where an object is no

[69] Minkowski, 1908.

longer represented by a single position, but by a worldline corresponding to the entirety of its spatiotemporal existence.[70]

However, this operation is already a visual betrayal: the real block universe is neither a stack of snapshots, nor a piling up of successive spatial slices, nor a frozen volume traversed by an observer, it is a geometrical whole of which no three-dimensional section can capture the totality. The difficulty is therefore not only to "think" the block universe, but to acknowledge that, strictly speaking, there is no possible faithful image of what a four-dimensional spacetime physically is. One is therefore forced to use the subterfuge of representing two spatial dimensions extended along the temporal dimension, according to two procedures that we might poetically call the "orchestral" representation and the "baker" representation (which are very similar).

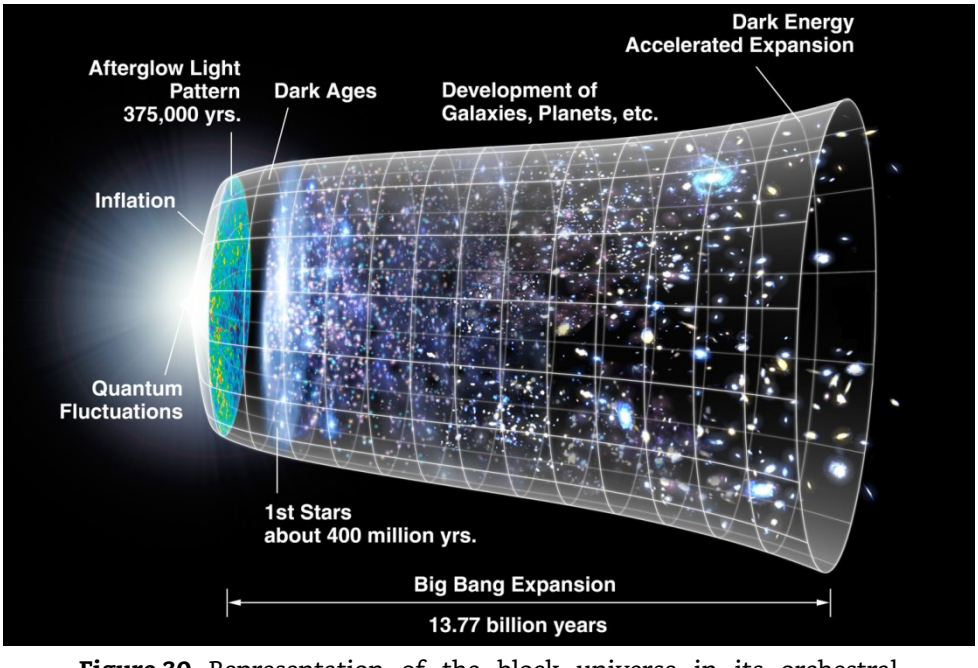


**Figure 30** Representation of the block universe in its orchestral version, shaped like a trumpet bell, which makes it possible to situate the different stages of its development from the Big Bang onward.

[70] It should be noted that Minkowski, at that point, considers only special relativity (without gravitation), as a special case of general relativity.

In the orchestral representation, the block universe is depicted as a flared volume, analogous to the straight trumpets of Antiquity, to angelic horns. The narrow mouthpiece corresponds to the initial instant, the Big Bang, where the whole of spacetime is concentrated in an extremely dense and hot region (just before, one often indicates the initial "singularity," this "primeval atom" of Georges Lemaître, whose size is nowadays placed approximately between one Planck unit—$1.616 \times 10^{-35}$ meter, lasting only $5.391 \times 10^{-44}$ second—and the infinitely small and brief). As one progresses along the temporal axis, the spatial volume widens, expressing the expansion of the Universe, then its increasingly pronounced flaring makes the accelerated expansion perceptible. Time is therefore no longer conceived as a succession of lived instants, but as a dimension along which the Universe is deployed in its entirety, from the most distant past toward an undetermined future, yet already included within the global geometry of the block.

This representation has the advantage of making visually accessible, within a single continuous object, the major phases of cosmic history: primordial epoch, nucleosynthesis, decoupling of radiation, possible inflation, formation of large-scale structures, progressive domination of the hypothetical dark energy. These phases are no longer events that "happen," but distinct regions of the spacetime block, like markers placed at different geometrical points.

The baker representation is based on a very similar image in principle, but conceptually more fruitful when it comes to thinking about the slicing of the block universe. The spacetime block is represented as an elongated loaf of bread, whose length corresponds to the temporal dimension and whose cross sections represent spaces at a given instant. This image immediately makes it possible to visualize that the block is not only a global volume, but an object that can be "sliced" along different planes, without these cuts having any privileged ontological status. A slice strictly perpendicular to the temporal axis corresponds to the intuitive idea of a global, homogeneous present, shared by all observers, but this cut only makes sense within an implicit Newtonian framework, already invalidated by relativity.

For the decisive interest of the loaf appears when the slice is tilted. An oblique cut through the block corresponds to a hypersurface of simultaneity proper to an observer in motion, and more generally to

a given frame of reference. Depending on its orientation, the slice includes regions that other observers would classify as past or future.

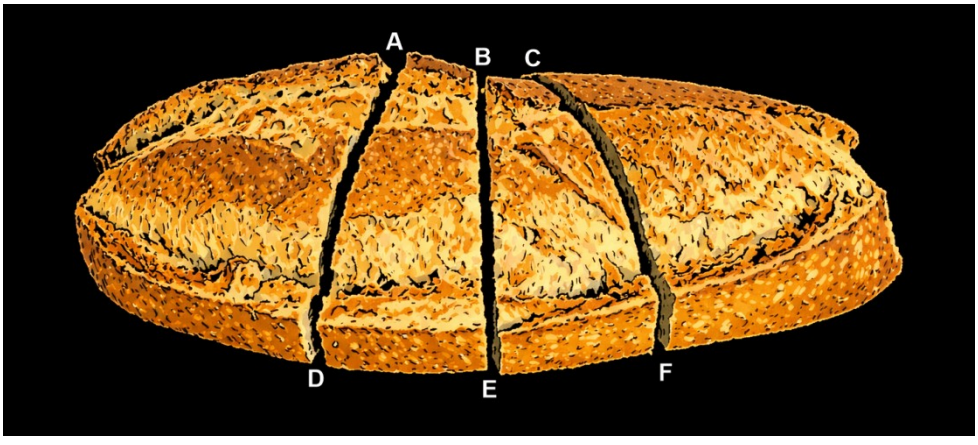


**Figure 31** Representation of the block universe in its baker's version, shaped like a loaf of bread, which makes it possible to visualize the effects of slicing oriented according to the motion of one body relative to another: toward the past (A–D, to the left) when the bodies are moving apart, or toward the future (C–F, to the right) when they are moving closer together. This explains why the proper times of bodies differ. The central position (B–E), corresponding to an absence of relative motion between bodies and thus to a simultaneity of times, is purely theoretical, since in the universe everything is always in motion.

For a super-traveler capable of traversing spacetime without relativistic constraint, these different slicings lead to radically distinct "presents," without physical contradiction, but with profound consequences for apparent causality and the ordering of events. The baker representation thus makes immediately visible the relative nature of simultaneity and dissolves the illusion of a natural foliation of the Universe. The block does not decompose into objective temporal layers; it is observers who impose their cutting planes, and therefore their partial reading of the four-dimensional whole.

It is important to keep in mind that, by graphical convention, the slice cut from the loaf is represented as two-dimensional, in order to remain graphically "representable." This bidimensionality is therefore purely conventional. One must constantly bear in mind

that each slice actually corresponds to a complete three-dimensional space, and that it is possible, through a controlled effort of imagination, to immerse oneself in it as in an ordinary volume. The slice then becomes an instantaneous fragment of the spacetime block, not an instant that "passes," but a full three-dimensional region, fixed within the four-dimensional whole. One can thus conceive this section as a snapshot of the Universe in three dimensions, a total spatial state extracted from the block (for example, a sphere of 880 billion billion kilometers if one limits oneself to the observable Universe), without any particular ontological privilege, and without implying an objective present. This mental immersion makes it possible to understand that what we call the Universe, at a given instant, is nothing other than an arbitrary section of the block, made familiar because it corresponds to the way our consciousness traverses and reconstructs spacetime.

**Presentism**

Presentism and eternalism constitute two opposing metaphysical frameworks in relation to the concept of the block universe. These two positions are not physical theories, but ontological [71] interpretations of time, that is, answers to the question of what truly exists in time.

Presentism is an ontological position according to which only what is present truly exists. The past no longer exists and the future does not yet exist. Existence is thus strictly indexed to the present instant, the only place where reality is fully given.

In this perspective, the world unfolds only within a three-dimensional space that evolves continuously. Future events do not exist in advance. They occur progressively as time flows, constantly producing new configurations of the world. These configurations do not accumulate to form a preexisting spacetime. As a four-dimensional totality, spacetime does not exist. Past states of the world do not persist either. Only the world as it is now has ontological reality.

[71] Ontology is a branch of philosophy, and more specifically of metaphysics, which, in its most general sense, seeks to define what Being is, independently of its particular determinations.

The past and the future therefore have, at best, only a conceptual existence (memories of the past, with the distortions we know, and imaginings of the future, just as uncertain, between probability and illusion). The past and the future are thus mental constructions, representations of what has been or what will be, but not regions of reality endowed with their own existence.

The presentist conceives of himself only in the present instant, in this boundary without thickness that separates what is no longer from what is not yet. The classical image associated with this conception of time goes back to Heraclitus, with the analogy of the river: the water that flows is constantly renewed, while the observer or the bather remains, in appearance, in the same place, unable to encounter the same reality twice.

In a presentist perspective, free will finds an intuitively favorable ground. If only the present truly exists, if the past is no more and the future is not yet, then the present instant becomes the ontologically privileged site of decision. Choice is not simply experienced as such, it is conceived as effectively open, not fixed, not inscribed anywhere other than in the very act of deciding. Since the future is not yet real, it cannot already contain the trace of what is going to be chosen; free will unfolds there as a genuine ontological indeterminacy.

This position grants consciousness a central, almost foundational role. The subject is not a mere point of passage within an already given structure, but an agent who contributes to bringing reality into being. The present is not merely a psychological marker, it is the only plane of existence, and it is precisely this exclusivity that makes possible the idea of a causality open toward the future. Free will is then not an illusion produced by local ignorance, but a property of the world itself, linked to the incompleteness of reality at each instant.

In return, this close link between presentism and free will entails a high theoretical cost. It becomes difficult to reconcile this view with the physical descriptions of time arising from relativity, where the present loses its universal and absolute character. Presentism protects free will by anchoring it in an ontology of becoming, but at the price of a persistent tension with relativistic spacetime, which instead suggests a global coexistence of events. To this tension is added another, just as structuring, with the determinism that runs through all the sciences: in a world where causes and effects follow

one another according to laws, the idea of a truly open choice becomes difficult to sustain. Free will thus gains in phenomenological evidence what it loses in cosmological comfort and in scientific coherence.

Historically, the presentist position was defended and justified by Duns Scotus[72] and then by Thomas Hobbes[73]. In the contemporary period, it is notably supported by authors such as Arthur Prior[74] and Ned Markosian[75].

**Eternalism**

According to the eternalist conception, time exists in its entirety and forms what physicists describe as a block universe. All events within it possess the same ontological status. There is no "present" reality endlessly renewing itself, but rather a total and timeless reality, already fully given. This reality, however, reveals itself to observers only in a progressive and partial way. We discover it only through the course of our own evolution, an evolution that the Newtonian conception assimilates to time itself.

Within this framework, existence is not limited to the present, but extends across the whole trajectory of existence. Every event that occurs, that has occurred, or that will occur, likewise exists, regardless of whether we know about it or not. Ignorance, memory, or anticipation in no way alter the ontological status of these events: they exist in the same way within the overall structure of space-time.

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[72] Scotus, circa 1290–1300. It is in the *Ordinatio*, notably in Book I, distinction 39, that Duns Scotus discusses the question of the present, of existence, and of the status of what is no longer or not yet, within the framework of his metaphysics of being and temporality.

[73] Hobbes, 1655. In his *De Corpore*, Thomas Hobbes develops a materialist conception of the world and of time, in which only what presently exists possesses full reality, while the past and the future fall under constructions of the mind based on motion and memory.

[74] Prior, 1967. In this foundational work, Arthur Prior develops "tense logic" and explicitly defends a sophisticated form of presentism, in opposition to atemporal conceptions of time derived from relativity.

[75] Markosian, 2004. In this reference article, Ned Markosian offers a systematic defense of presentism, in response to contemporary objections, notably those arising from relativity and eternalism.

The eternalist thus conceives of his existence as a complete story, a continuous totality running from birth to death. Consciousness does not create time, it moves through it. The succession of states of consciousness produces the impression of a temporal flow, but that flow corresponds to no objective reality. Whether one is dealing with the universal time of Newtonian physics or the proper time of relativistic physics, the "passage of time" is not a fundamental property of the world, but a modality of our relation to space-time. Eternalism is the block universe illusorily experienced in the presentist mode.

This conception finds an ancient precursor in Parmenides[76], for whom being is one, immobile, and eternal, while every appearance of becoming belongs to illusion. In our time, philosophers such as Bertrand Russell[77], John Jamieson Carswell Smart[78], Willard Van Orman Quine[79], Adolf Grünbaum[80], and Paul Horwich[81] have defended, in various forms, atemporal conceptions of time closely compatible with eternalism and with the vision of the block universe.

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[76] Parmenides, early 5th century BCE. In Fragment 8, Parmenides sets out the thesis of being as one, immobile, eternal, neither generated nor perishable, and establishes the radical opposition between being and the illusion of becoming.

[77] Russell, 1915. In this central text, Bertrand Russell defends an atemporal conception of time, distinguishing the order of events from the psychological experience of the passage of time.

[78] Smart, 1949. A classic article in which Jamieson Carswell Smart criticizes the idea of an objective flow of time and supports an atemporal conception compatible with eternalism.

[79] Quine, 1960. Although not devoted exclusively to time, this work by Willard Van Orman Quine sets out a naturalistic and atemporal ontology in which temporal distinctions belong to language and theory, not to an objective becoming.

[80] Grünbaum, 1973. This is a reference work on space and time in physics, in which Adolf Grünbaum explicitly defends an eternalist interpretation and critiques any notion of an objective passage of time.

[81] Horwich, 1987. This is a major book by Paul Horwich, analyzing temporal asymmetries without appealing to a flow of time, and proposing an account fully compatible with eternalism and the block universe.

This opposition between presentism and eternalism does not, however, bring the debate to a close, because some philosophers, such as John Ellis McTaggart, have defended an even more radical thesis, calling into question the very reality of time. McTaggart's[82] approach is not to defend eternalism against presentism, but more radically to show that time, as such, is unreal. To do so, he distinguishes two fundamental ways of ordering events: the *A-series* (past, present, future) and the *B-series* (earlier than, later than, simultaneity).

The *A-series* clearly corresponds to a presentist, or at least temporal, view of time, since it relies on a moving present. McTaggart attempts to show that this series is contradictory, because for an event to be successively future, present, and then past, it must be assigned incompatible properties, which leads either to a logical contradiction or to an infinite regress (to explain the succession of an event's temporal properties, one must introduce a second temporal order tasked with explaining this change, which in turn calls for a third order, and so on, without any ultimate explanation ever being reached). From this perspective, McTaggart's attack on presentism is systematic and, in his view, decisive.

However, McTaggart does not thereby retreat into eternalism in the modern sense. Certainly, the *B-series*, devoid of any privileged present, avoids the contradictions of the *A-series* and closely resembles what contemporary physicists and philosophers will later associate with the block universe. But McTaggart considers that the *B-series*, taken on its own, is insufficient to account for real change. For him, a time without genuine change does not deserve the name of time. The *B-series* describes an order, but not a becoming. It is precisely on this point that he implicitly rejects eternalism, not because it would be incoherent, but because it would be ontologically too impoverished to ground a real temporality.

This results in a singular and deeply unsettling position. McTaggart rejects presentism because it is contradictory, and rejects any form of atemporal eternalism because it fails to account for change. The philosopher therefore concludes that time itself is unreal.

[82] McTaggart, 1908.

McTaggart never fully articulates a positive alternative, which is largely explained by his metaphysical idealism. For McTaggart, ultimate reality is atemporal, structured by logical and spiritual relations that go beyond both presentism and eternalism. From this point of view, his apparent silence regarding any explicit adherence to eternalism is not an accidental gap, but the direct consequence of his philosophical project. Faced with an eternalism illusorily experienced in the presentist mode, it is not eternalism that fails to account for change, but McTaggart himself; his "unreality of time" marks the very admission of this failure. It is not time as a fourth dimension in the block universe that does not exist, but McTaggart and his inability to grasp his own emptiness.

The eternalist conception of time now stands as the framework most compatible with contemporary physics, particularly with relativity and its conceptual extensions. Without constituting an explicit dogma, it underlies many theoretical reflections, extending to the consideration, among physicists such as Stephen Hawking[83], Igor Novikov[84], and Kip Thorne[85], of the possibility of time travel and, correlatively, the existence of associated multiversal structures.

Within this four-dimensional perspective, individuals are no longer conceived as strictly present entities, but as beings extended in time, "space-time worms,"[86] as David Lewis[87] puts it, each lived instant being only one phase among others. Personal identity then resides neither in a privileged present nor in an objective flow of time, but in the continuity and connectivity of the phases that

[83] Hawking, 1992. The well-known article in which Stephen Hawking explicitly discusses the possibility of time travel via closed timelike curves and proposes the chronology protection conjecture (an *ad hoc* hypothesis according to which the laws of physics prevent the formation of closed timelike curves allowing travel into the past, in order to preserve causal consistency and avoid temporal paradoxes).

[84] Novikov, 1989. A work in which Igor Novikov introduces and develops the principle of self-consistency applied to closed timelike curves, within a fully relativistic and eternalist framework.

[85] Thorne, 1994. In this reference book, Kip Thorne examines in detail relativistic solutions allowing time travel (wormholes, closed timelike curves) and their ontological implications.

[86] For a clear illustration of "space-time worms," see Tegmark, 2014, p. 365.

[87] Lewis, 2015.

compose an entire existence, already inscribed in the overall structure of the block universe.

Reducing the block universe to a mere possibility of "time travel" is no doubt to shift the problem rather than to confront it. This somewhat sensationalist focus (one irresistibly thinks of science fiction literature) obscures the essential stakes, far deeper, that the block universe brings to light. First, the issue of consciousness, and in particular the subjective experience of a flow, as well as the issue of free will, within a framework where the future is already inscribed in the overall structure of space-time, including our brain and its most refined functioning. If all events equally exist, then the question is no longer whether one can travel through time, but how a localized consciousness comes to represent an open future, to make choices, and to perceive itself as the cause of its actions.

Within an eternalist perspective, free will is immediately weakened, at least in its most intuitive sense. If past, present, and future all equally exist within a block universe, then future events are already there, inscribed in the overall structure of space-time. Choice thus seems to lose its status as an open possibility and instead becomes a local fact among others, situated along a worldline already entirely given. The feeling of deciding freely then appears as an internal experience, real on the psychological level, but no longer corresponding to any ontological indeterminacy. All the more so since this "internal experience" itself, as a product of our brain, is also inscribed in the future of the space-time fabric, turning the feeling of choice into a permanent illusion. The flag: "Look! I am free! Look how I wave, twist, and contort by my own will! Look, I do whatever I want!" it says, stirred by the wind.

However, eternalism does not necessarily imply a naive determinism nor a pure and simple denial of free will. A reformulation is possible, at the cost of a conceptual shift. Free will is no longer understood as the capacity to bring about several possible futures from a privileged present, but as the internal coherence between an agent's mental states, his reasons, his desires, his beliefs, and the actions that unfold along his worldline. Choice is real as a local causal process, even if it is already included within the totality of the block universe.

Within this framework, freedom no longer resides in the openness of the future, but in the absence of external constraint on

the agent. An action is free if it proceeds from the agent himself, even if one admits that, seen "from the outside" of the block, it is already determined. The internal point of view and the global point of view do not contradict one another; they describe two distinct levels. Free will thus becomes compatible with eternalism, provided one abandons the idea that freedom requires a fundamental indeterminacy of the future, and accepts that it can be inscribed within a structure already entirely given. In other words, the block universe is eternalism illusorily experienced in the presentist mode.

In this same perspective, free will appears to be only the first in a series of illusions generated by our local immersion within the block, alongside other existential phantasmagorias such as consciousness, the self, the flow of time, space as a container, linear causality, motion, energy, forces, fields, or even the laws of nature as we formulate them.

The block universe nevertheless remains a physical reality, directly arising from relativity, and as such difficult to contest. It does not resolve anything by itself, but it imposes a framework within which certain fundamental intuitions must be rethought, at the cost of considerable but unavoidable conceptual tensions.

**A physical ontology of the block universe**

This section opens with a clarification of an ontological nature. The aim here is not to describe how we come to know the block universe, nor the instruments, models, or procedures by which we measure it, but to formulate what the block universe is, in the most direct sense that physics allows. A cosmological description of the block universe can be said to be ontological insofar as it does not merely line up equations or operational devices, but asserts a mode of existence of space-time itself. By definition, the universe is here conceived as a four-dimensional totality, within which past, present, and future events coexist as distinct regions of a single global structure.

There is no question of introducing a metaphysical ontology detached from physics, nor of standing above theories by means of categories foreign to their content. The ontology at issue here is informed by relativistic cosmology itself. It emerges from what the formalism, the principles of relativity, and cosmological

observations make sayable about the being of the universe. In this sense, it does not precede physics; it is a controlled interpretative consequence of it.

Speaking of a "physical ontology of the block universe" is therefore not only acceptable, but conceptually rigorous, provided that this anchoring point is explicitly maintained: physics. The task is to describe the universe as relativistic cosmology allows us to think it as a totality, not to project onto it an abstract speculation. The ontology proposed here does not add itself to cosmology; it makes explicit its minimal ontological scope, which becomes necessary as soon as one takes seriously the idea of a global space-time.

Our arbitrary descriptive starting point (one must make a choice) is the total universe, taken as the "unit" of the space-time block. This total universe contains all of space at a given age of the universe, populated by hundreds of billions of galaxies, forming a homogeneous gas on large scales, and of a size far greater than 87 thousand billion billion kilometers[88]. It can be represented as a sphere or hypersphere, within which we are located, and which must be imagined not as a final point, but as a stage within the complete course of a universe forming a space-time block.

Next, the block universe is a series of these spheres or hyperspheres, which must be imagined, through visual transparency, as succeeding one another within the block. This "succession" is not a real unfolding in time, but a spatiotemporal geometric order.

Finally, the block universe can be visualized as a "tube" whose cross-section varies continuously, widening from the Big Bang to the present day, with a universe in continuous and accelerated spatial expansion. This tube begins at a more than minuscule size, associated with the initial singularity and the Planck scale, and extends to a size greater than 87 thousand billion billion kilometers

[88] The actual spatial slice may be finite and immensely larger, or strictly infinite. The needs of this arbitrary representation require a quantified definition of size, from which it becomes possible to visualize a sphere or hypersphere (thus a volume bounded by an edge), whereas choosing infinity would amount to visualizing a sphere or hypersphere without a boundary, which is more difficult to conceive!

at the present epoch. And, like travelers in a tunnel, we can see inside the tube: this is what all spatiotemporal astronomical exploration shows us: "to see far is to see into the past."[89]

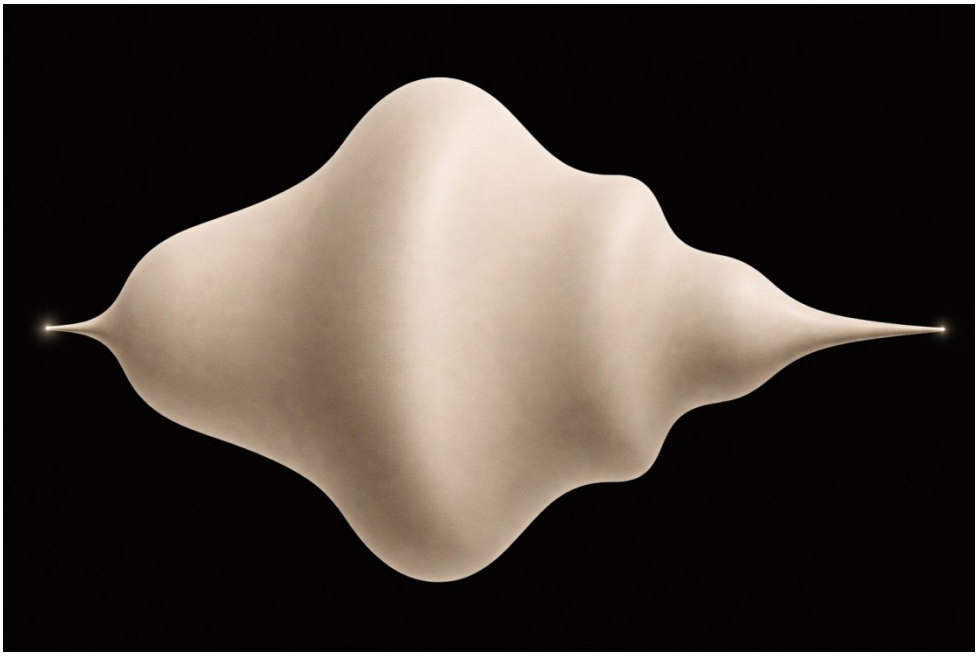

**Figure 32** Diagram representing the block universe as a tube deformed by the stages of its geometric evolution, between two singularities, from the Big Bang through the different regimes of expansion, inflation, and contraction, up to a Big Crunch. This is an orchestral version in which only the volume is represented.

Two clarifications are nonetheless required: (1) this tube extends beyond our apparent present, including the entire future of the universe, which, depending on the models, may correspond either to an indefinite expansion and an extreme dilution of matter-energy, or to a recontraction leading to a Big Crunch[90]; (2) this "tube" obviously

[89] We will examine later the questions of entropy and the arrow of time that explain why we cannot see "toward the future."

[90] Some data tend to suggest a gradual decrease in the acceleration of the expansion over the past ~2.5 billion years, whereas it was more pronounced around 7 billion years ago, raising the possibility of a Big Crunch ending for our universe. Dear reader, which would you prefer: evaporation or a recompression toward the primordial atom? An idea still at the heart of lively debates among scientists since 2025. To be continued…

exists only in representation, not in physical reality, the block not being embedded in an external space in which it would have a shape. However, defining this "shape" is a way of moving toward its multiversal multiplication: it is indeed a set of such shapes that forms a multiverse.

**Laplace's demoness**

Pierre-Simon Laplace was a mathematician, astronomer, and physicist spanning the eighteenth and nineteenth centuries. In 1814, in his *Essai philosophique sur les probabilités* (Philosophical Essay on Probabilities)[91], Laplace formulated an intriguing thought experiment. He imagined: "An intelligence which, at a given instant, knew all the forces that animate nature and the mutual positions of the beings that compose it, if this intelligence were vast enough to submit these data to analysis, would embrace in a single formula the movements of the greatest bodies of the universe and those of the lightest atom; for such an intelligence nothing would be uncertain, and the future just like the past would be present before its eyes." Much later, this hypothesis of deterministic omniscience was taken up in nineteenth-century philosophical debates under the name of "Laplace's demon."[92]

In a certain sense, one can note a convergence between Laplace's demon and the block universe, but they are not identical. The demon presupposes a dynamic determinism: given complete knowledge of the state of the world at a given instant, and of its laws, an intelligence could calculate the entire past and the entire future. Time nevertheless remains a parameter of evolution, but the future is, in principle, already contained in the present. The block universe, by contrast, is an ontological thesis arising from relativity: past, present, and future coexist within a single four-dimensional space-time block. There is no longer any "calculation" of the future from the present; the future is already there, as another region of the block.

One may say that Laplace's demon is the epistemic image of a world that, ontologically, resembles a block universe. The demon analytically traverses what the block contains geometrically. Yet

[91] Laplace, 2020.

[92] An expression coined by his biographers.

Laplacian determinism does not necessarily imply relativistic eternalism. It remains compatible with a more classical view of time as a parameter, so long as the laws are reversible and deterministic. In short, the demon would be a fictional consciousness capable of "reading" the internal geometry of the block, not of producing it.

However, in order to do its job, our "demon" would require complete and exhaustive information about the microscopic state of the entire universe, strictly deterministic laws valid at all scales, and a computational power at least equivalent to that of the universe itself. Even a supercomputer would not suffice. Laplace's demon would need, quite simply, a position outside the world rather than a universal computer.

**Figure 33** Whimsical artist's depiction of worldlines, crossing the screen from right (the past) to left (the future), which a mischievous Laplace's demoness playfully stirs, indifferent to the effects she induces in phenomena.

So let me introduce you to the demon's twin sister: Laplace's demoness, who possesses far greater powers than her famous brother. A feminine entity, weak in mathematics, like all her peers: [93]

[93] We are in the realm of cliché, caricature, and humor, of course.

she does whatever she wants! And where the demon must laboriously calculate… she sees! Placed outside the block universe, she does not need to infer the future from the present: she grasps in a single glance the entirety of the space-time block. For her, past, present, and future are not three distinct regions (indeed, for her, that makes no sense), but a single four-dimensional architecture, entirely given.

Our cunning demoness does not merely contemplate. She can also enter the block, grasp with both hands a bundle of worldlines—those of particles, of a star, of a conscious being, of you, of me…—and "shake" it! And this greatly amuses our mischievous demoness, for this gesture does not merely modify the past already elapsed or the future yet to come, but deforms the geometry of space-time itself. Causal relations, seen from the inside, appear completely disrupted, while from the outside they are nothing more than rearrangements of trajectories within the universal totality.

But that is not all! For this powerful demoness can also choose a slice of the block, a hypersurface corresponding to what we call an "instant." She enters it as one would enter a cross-section of a loaf of bread, at any point within the block, observing that everything there is simultaneous, perfectly motionless, spread out without distinction between past and future. Time, in this slice, is no longer a flow, but a suspended dimension. Playful and curious, Laplace's demoness thus amuses herself by traveling within the block universe, leaping from the cosmic microwave background, 380,000 years after the Big Bang, to the Egypt of the pharaohs three thousand years ago, then returning in the blink of an eye to the formation of the very first galaxies billions of years ago, or jumping to the fourth millennium CE, to a kind of overheated planet where, humanity having disappeared, only a few well-adapted animals survive… and so on.

**CONCLUSION**

To make the Big Bang model perceptible within the framework of the block universe, it is useful to introduce a simple visual representation of the spatial growth of the universe. The table that follows thus proposes to read cosmological history as the progressive variation in the diameter of the "tube" of the block universe across the major epochs. Each row corresponds to a global spatial slice at a

given age, characterized by a typical size of the universe at that moment. These are not exact measurements, but orders of magnitude intended to provide a geometric intuition of cosmic expansion, from the very first scales of the Big Bang to the current minimal bound of the total universe. This visualization makes it possible to grasp at a glance how the standard Big Bang narrative is inscribed within a global, continuous spatiotemporal structure already entirely given in the block universe.

This table (below) highlights a central ontological point: within the framework of the block universe, the universe taken as a spatiotemporal totality constitutes a genuine physical unit. This unit is not a mere "observable universe," nor a particular phase of cosmic history, but a complete block, integrating all its ages. It is precisely this physical ontology that makes the multiverse conceptually possible, understood as a set of such distinct block universes.

***SIZES OF THE BLOCK UNIVERSE***
**(diameters of the "tube")**

| |
|---|
| *Initial singularity*<br>(Planck scale: $10^{-35}$ m) |
| *End of the inflationary era*<br>(on the order of a millimeter to a few centimeters) |
| *Primordial nucleosynthesis*<br>(a few minutes) (on the order of 1 million kilometers) |
| *Radiation–matter decoupling (380,000 years)*<br>(on the order of 1 trillion kilometers) |
| *Formation of the first galaxies (a few hundred million years)*<br>(on the order of 10 trillion kilometers) |
| *Matter-dominated universe (after a few billion years)*<br>(on the order of 100 trillion kilometers) |
| *Present observable universe (at 13.8 billion years)*<br>(approximately 9.5 quadrillion trillion kilometers) |
| *Present total universe (lower bound)*<br>(greater than 87 thousand trillion trillion kilometers or ∞) |

From there, one can envisage types of cosmic plurality, as proposed by Max Tegmark with his four "levels" of multiverse. These levels are defined according to a descriptive logic and correspond to

variations in physical laws, constants, or even underlying mathematical structures. The block universe thus provides the basic unit from which an entire multiversal hierarchy can coherently unfold.

# 2. Multiverses by type

Max Tegmark proposes a classification of multiverses into four "levels," in which universes differ respectively by their spatial extension (Level I), their constants or effective laws arising from eternal inflation (Level II), quantum branches (Level III), and fundamental mathematical structures (Level IV)[94].

We will take up this approach following a cosmic logic, that is to say, a logic that organizes multiverses relative to one another within a hierarchical structure of nesting. This will allow for a global and exhaustive cosmological construction. We will therefore speak of "types" of multiverses. The four types of multiverses, which will be developed separately, are:

**Type 1 multiverse:** a mathematical multiverse. It corresponds to the overall architecture of coherent structures. The mode of variation is the multiplicity of mathematical structures themselves, that is, a variation of structure. This multiverse encompasses multiverses of types 2, 3, and 4.

**Type 2 multiverse:** a global inflationary multiverse (eternal inflation). It consists of the multiplicity of post-inflationary universes within a single fundamental mathematical structure. The mode of variation is a variation of parameters. This multiverse encompasses multiverses of types 2 and 3.

**Type 3 multiverse:** a spatial multiverse (the infinite expansion of a post-inflationary universe). It corresponds to the multiplicity of observable regions within a given universe. The mode of variation is a variation of spatial position. This multiverse encompasses the type 4 multiverse.

**Type 4 multiverse:** a modal quantum block multiverse (Everett's many-worlds interpretation). It designates the multiplicity of coexisting versions of the same world. The mode of variation is a variation of state.

Before entering into a detailed examination of the four types of multiverses, we must first make explicit two conceptual matrices that silently guide their interpretation: the repetition of the same

[94] Tegmark, 2003ab, 2014.

and the multiplication of the possible. As Luminet recalls[95], the first finds a radical formulation in Louis Auguste Blanqui, a French socialist revolutionary, for whom an infinite space and a finite combinatorics imply the exact reproduction of configurations (the repetition of the same), all the way to our exact doubles scattered across the cosmic expanse. The second conception receives an analytical articulation in David Lewis, an American philosopher, with modal realism, in which each logical possibility possesses its own consistency (the multiplication of the possible). Between strict duplication and modal proliferation, these two poles delineate the theoretical horizon within which multiverses of types 1 to 4 will take shape.

**The repetition of the same**

The repetition of the same is stated, in its most radical form in the nineteenth century, by Louis Auguste Blanqui, not in an academic treatise on cosmology, but in a short work written in captivity at the Fort du Taureau in 1871: *L'Éternité par les astres* (Eternity Through the Stars)[96]. The context matters. After the crushing of the Paris Commune, Blanqui is imprisoned and cut off from the political action that had structured his entire existence. It is in this forced isolation that he redirects his speculative energy toward the sky. He relies on the Newtonian cosmology dominant in his time: an infinite, homogeneous space, populated by an infinity of stars distributed without center or edge. To this, Blanqui adds an implicit but decisive hypothesis of two finite numbers: (1) that of the possible combinations of matter within a given volume; (2) that of the elements. From that point on, within an infinite expanse, all configurations must repeat, and repeat an infinite number of times. Our world, with its precise history, its singular individuals, its contingent gestures, is only one instance among an infinity of strictly identical instances scattered throughout space. The repetition is not cyclical in time, it is spatial; it does not involve a return, but a duplication.

At the time, the reception of this text was marginal. Blanqui was not recognized as a scientist, and his name remained associated with

[95] Luminet, 2001, p. 189.

[96] Blanqui, 2012.

insurrection and conspiracy. Nineteenth-century astronomers did not see in it a scientific contribution, but a speculative curiosity coming from a defeated militant. The work was not part of any scholarly institution, proposed neither new calculations nor new observations. Without realizing it, it extrapolated, with a certain logical rigor, the premises of classical cosmology. It therefore remained on the margins, cited sporadically as a literary or political singularity rather than as a cosmological thesis. Yet its reasoning anticipates, in its structure, combinatorial arguments that would reappear in the twentieth century as soon as the hypothesis of a statistically homogeneous infinite space was again accepted.

The resurgence of the idea occurs indirectly. In the twentieth century, with the extension of the cosmos beyond the Milky Way, then with the expansion models derived from general relativity, the hypothesis of a globally infinite space once again becomes physically thinkable. From that point on, the combinatorial argument regains its force: if physical conditions are realized everywhere with an ergodic distribution, that is, one that "explores all possibilities," then the configurations compatible with the laws necessarily repeat.

Blanqui is thus rediscovered *a posteriori* as a precursor of a thesis that contemporary cosmology reformulates in a statistical rather than speculative language. What was, in 1871, the solitary meditation of a prisoner deprived of escape becomes, within a renewed theoretical framework, an almost mechanical consequence of an infinite space filled with matter combinable into a finite number of configurations. The repetition of the same ceases to be a philosophical provocation; it becomes a possible corollary of a certain cosmological ontology.

### The multiplication of the possible

The multiplication of the possible finds its most systematic formulation in the twentieth century in the work of David Lewis. The context here is analytical and academic: Anglo-American philosophy of the nineteen-sixties to nineteen-eighties intensely develops *modal logic*[97], with possible worlds serving as semantic

[97] Modal logic is a branch of logic that studies the notions of necessity and possibility by means of formal operators ("it is necessary that," "it is possible that"). It often draws on the theory of possible worlds to make its

tools to analyze necessity (what cannot not be) and contingency (what could be otherwise). As we shall see, Lewis radicalizes this conceptual tool.

In *On the Plurality of Worlds*[98], Lewis argues that these worlds are not mere logical fictions or linguistic devices, but concrete realities, as actual as our own. Each world is a spatiotemporal whole closed upon itself. They are causally isolated from one another, without interaction or overlap. The possible is not an abstract reserve of scenarios; it is ontologically realized.

The thesis thus arises from a technical debate about the status of modal quantifiers, but it quickly extends beyond the logical framework to become a general ontology. Whereas the argument of the repetition of the same proceeds from a finite combinatorics inscribed within an infinite space, the multiplication of the possible proceeds from a principle of modal plenitude: every coherent, possible configuration, given a logical structure, exists in a world. What we then have is a maximal diversification across a plurality of disjoint totalities. Two strictly similar individuals may exist in two different worlds, but they are not the same individual; they are *counterparts*.

The reception of this theory was intense and controversial. Many saw in it an extravagant ontological inflation, disproportionate to its explanatory benefits. Others recognized the unifying power of the framework: by treating possible worlds as real, Lewis simplifies modal semantics and avoids multiplying *ad hoc* distinctions between fiction, abstraction, and reality. Since then, what has come to be known as *modal realism* has remained a minority position, but an unavoidable one. It constitutes the conceptual pole of the multiplication of the possible: no longer the necessary repetition of the same arrangement in infinite space, but the actuality of all logically admissible variations, each carried by an autonomous totality.

The repetition of the same and the multiplication of the possible can be understood as two complementary conceptual dynamics which, when superimposed, outline the architecture of a fractal. The first posits that within a given structure, as soon as material

functioning explicit.

[98] Lewis, 2007.

combinations are finite in number and extension is unbounded, certain configurations must reappear identically: the same reproduces itself. The second affirms that every logically coherent configuration possesses its own domain of actuality: the possible unfolds. If one thinks these two principles not as mutually exclusive, but as intertwined, the repetition of the same operates within each domain, while the multiplication of the possible differentiates the domains themselves. One thus obtains a stratification in which each level repeats certain structures and diversifies others, according to a logic of ontological inclusion. It is on this double foundation, internal duplication and modal proliferation, that our definition of a fractal omniverse will later be built.

**Type 1 multiverse**

The ontological status of the type 1 multiverse is mathematical. This multiverse corresponds to the overall architecture of coherent mathematical structures, therefore possible in the Lewisian sense. The mode of variation is thus the multiplicity of mathematical structures themselves. They define an infinity of highly varied universes within the type 2 multiverse.

As Tegmark[99] tells us, the type 1 multiverse (Level IV in this author's classification) is "strange." The first strangeness is that we do not yet know the mathematical structure underlying our own Big Bang universe. To do so, we would need to construct a "Theory of Everything," which would integrate quantum gravity and explain everything, but which is still under development among physicist-mathematicians.

Yet, as Tegmark emphasizes, this strangeness is nothing new. As physics has freed itself from ordinary intuition, it has incorporated phenomena that initially seemed disconcerting: the dilation of time at high velocities, the existence of extreme gravitational condensations such as black holes, quantum superposition in which a particle is not localized at a single point, the superfluidity of helium that climbs along container walls, or high-energy transitions in which particles change their nature. What once conflicted with common sense has become familiar to the physicist.

[99] Tegmark, 2004.

John Archibald Wheeler repeatedly questioned the nature of our universe in a radical way: "Why these equations, and not others?" By "equations," he meant the entire mathematical framework used to describe reality. Let us take two examples: Isaac Newton's law of gravitation, $F = G \times (m1 \times m2)/r^2$, or the famous relation of energy–matter equivalence in Albert Einstein's relativity, $E = m \times c^2$. Why such equations and not others? That is Wheeler's question. And this question applies to the entire formal corpus of equations that govern the physical world. Why is it precisely this system of equations that structures the world? Why do the fundamental laws take this form rather than another, equally conceivable from a logical standpoint? Among all possible mathematical structures, why does cosmic dynamics fall under general relativity, the standard model of physics, and quantum mechanics, rather than under another equally coherent framework? Why does $G$ have the value $6.674 \times 10^{-11}$ $m^3 \cdot kg^{-1} \cdot s^{-2}$? Why is the speed of light 299,792,458 meters per second? Why does the Planck constant $h$ have the value $6.626 \times 10^{-34}$ joule second? Why such masses for elementary particles?

Or again, why are the laws of physics identical regardless of the place or epoch at which they are tested? Why do the laws of physics remain the same in every direction in space? Why do all observers in uniform motion describe phenomena using the same laws? Why is electric charge always exactly conserved? Why does nature distinguish left from right in the weak nuclear interaction but not in electromagnetism or the strong nuclear interaction? In short, why does the fundamental mathematical architecture of reality have exactly this configuration, and not another equally mathematically conceivable one?

All these questions are crucial, because their answers define what our universe is. A few examples. If the fine-structure constant $\alpha \approx 1/137$ were to increase by a few percent, the electromagnetic force would bind electrons much more strongly to atomic nuclei. A variation on the order of four to five percent would suffice, according to several studies, to render certain atomic nuclei unstable or to drastically alter chemistry. Conversely, a comparable decrease would weaken atomic bonds: complex molecules would then become difficult to stabilize.

If the gravitational constant $G$ were larger by a factor of two to ten, the contraction of molecular clouds would be faster, stars would

be more massive, hotter, and their lifetimes much shorter, dropping below a few tens of millions of years—too brief to allow for complex biological evolution. If $G$ were smaller by a comparable factor, gravitational collapse would become too inefficient: star formation would become rare, or even impossible in certain scenarios.

For the cosmological constant $\Lambda$[100], the effect is even more spectacular. If its value were larger by a factor on the order of ten to one hundred compared to the observed one, accelerated expansion would prevent matter from aggregating into galaxies. If it were negative and of slightly greater magnitude, the universe would collapse too rapidly into a Big Crunch, before the formation of stable stars.

The mass difference between the neutron and the proton, about 1.3 megaelectronvolts, is also critical. A variation of just a few percent would suffice to prevent the stability of hydrogen or to radically alter primordial nucleosynthesis. Without stable hydrogen, there is no water and no organic chemistry.

Finally, if the strong nuclear interaction were weaker by a few percent, deuterium would no longer be stable; the chain of nuclear reactions in stars would be blocked. If it were stronger by a few percent, almost all primordial hydrogen would have fused into helium within the first minutes, leaving no fuel for long-lived stars. These examples show that modest variations, sometimes of only a few percent, are enough to profoundly transform nuclear structure, atoms, molecules, chemistry, biology, and stellar cosmology.

The type 1 multiverse thus opens the field to a plurality of universes founded on different mathematical architectures: modified constants, parameters adjusted differently, laws structured according to other formal equilibria. Some would give rise to stars and galaxies, others would remain without durable structures; some would allow complex chemistry and forms of life, others would remain biologically sterile.

[100] The cosmological constant $\Lambda$ is the term added by Einstein in his equations to keep the universe static. Interpreted as a uniform energy density of the vacuum, it corresponds to what is now called dark energy, responsible for the acceleration of cosmic expansion (the universe is therefore not static).

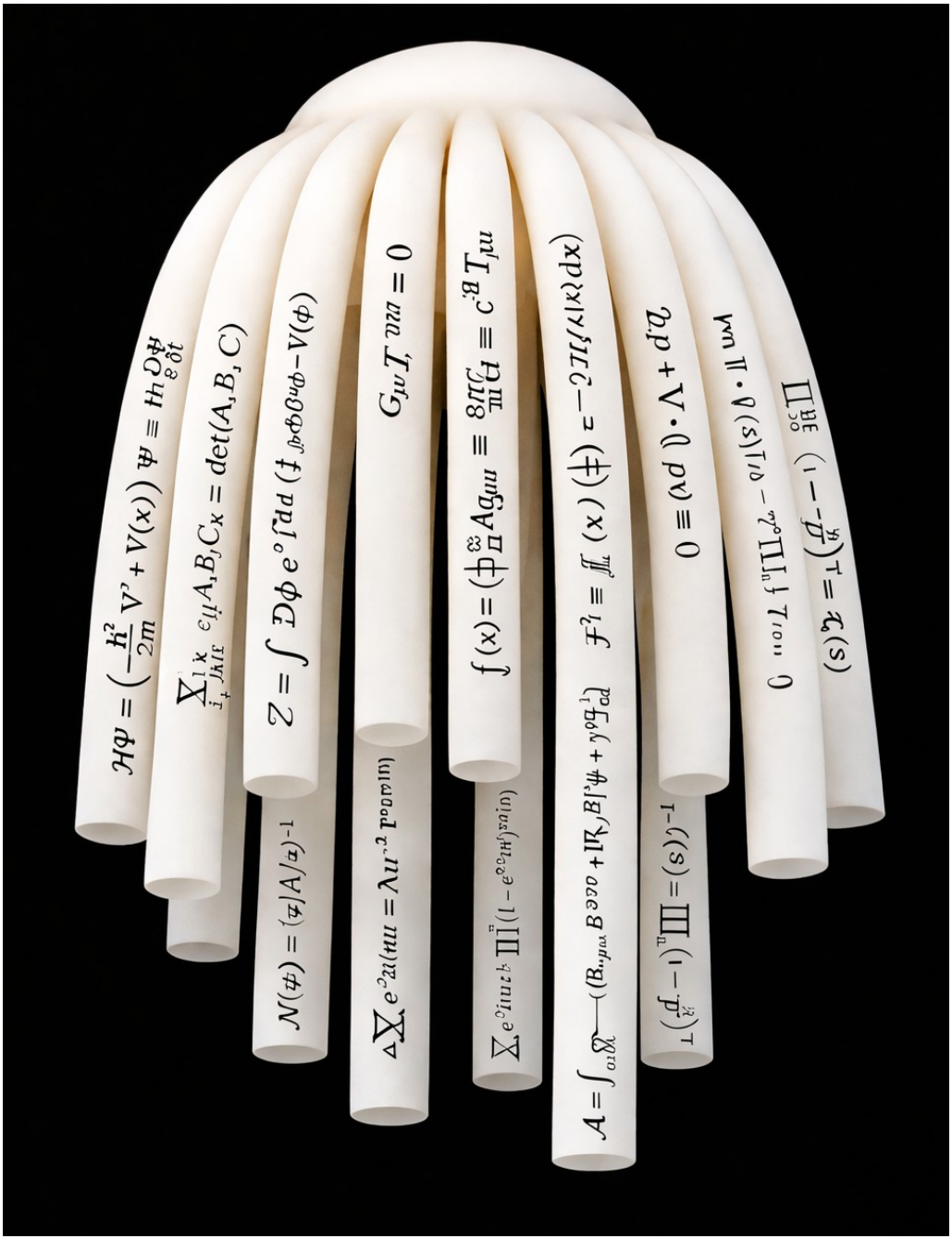

**Figure 34** Artist's representation of the Type 1 mathematical multiverse. Each tube symbolizes the generation of a multiverse according to a particular mathematical structure. As for where the mathematical multiverse comes from, the reader is invited to refer to the Leibnizian question: why is there something rather than nothing?

The mathematical multiverse is not limited to varying constants within the same inflationary framework. The type 1 multiverse encompasses all coherent mathematical structures, and therefore also all possible geometries, all dimensionalities, all metric signatures[101], and all conceivable dynamics. Some structures may resemble continuous, discrete, or fractal spaces, others may correspond to exotic topologies.

Within this perspective, a "universe" may be based on a space with three spatial dimensions like ours, but also on two, four, or more; on a Euclidean, hyperbolic, or elliptic geometry[102]; on a simply connected or multiply connected topology; on local or non-local laws; on continuous fields or discrete graphs. Some universes undergo an inflationary phase followed by an exit from inflation, after which expansion may continue under different physical regimes (effects of dark energy, as in our universe), while others remain in perpetual inflation; some may be static, others cyclic, others still devoid of time in the sense we give it. The variation then concerns the very framework of the structure: it is no longer merely the parameters of a given model that change, but the type of space, the number of degrees of freedom, the nature of fundamental objects, and the relations that unite them.

Understood in this way, the type 1 multiverse does not contain only universes "tuned differently," but geometrically and structurally heterogeneous universes. Our inflationary universe with three spatial dimensions (and a distinct temporal dimension) is only a particular case within a much larger set of possible mathematical forms, some of which bear no resemblance at all to what we call a cosmos.

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[101] The metric signature is the way in which time is distinguished from space in the formula that measures distances in the universe. In our universe, there is a difference for time compared to the three spatial directions. We have three directions of space and one direction of time. This difference means that time does not behave like a simple spatial direction: one cannot move freely within it (toward the past or the future) as one does in space.

[102] See the chapter on *The geometries of the universe*.

**The type 2 multiverse**

The ontological status is that of a global inflationary multiverse (eternal chaotic inflation[103]). The mode of variation consists of a multiplicity of post-inflationary universes within a single underlying mathematical structure. The variation is a variation of parameters. The type 2 inflationary multiverse defines an infinity of highly diverse spatial universes of type 3.

In the nineteen seventies, the Big Bang model became established as the physical account of cosmic history. It is not an explosion in space, but an expansion of space itself, accompanied by rapid cooling. In the first minutes, primordial nucleosynthesis takes place, forming light nuclei (hydrogen, helium, traces of lithium). Before about 400,000 years, the universe is a hot plasma of protons, neutrons, and photons that constantly collide with free electrons, which traps the photons and makes the universe opaque. Light tries to move forward, but it keeps bouncing off free electrons. Then, under the effect of expansion and cooling, electrons attach to nuclei (protons and neutrons) to form atoms (hydrogen and helium), the plasma fog disappears: light can finally travel in straight lines, and the universe becomes transparent. This radiation still exists today in the form of the cosmic microwave background. Then gravity amplifies the initial inhomogeneities, leading to the collapse of matter into increasingly complex structures: galaxies, stars, planets.

Yet, troubling questions remained about what had happened at the very beginning, taking the form of four problems:

– **The origin problem:** did something arise from nothing?

– **The monopole problem:** where did all the superheavy particles called magnetic monopoles[104] go, which were created very early on?

[103] "Chaotic" does not mean an absence of organization, but refers to the sensitivity to the initial quantum fluctuations of the inflationary field.

[104] Magnetic monopoles are hypothetical particles predicted by certain grand unified theories developed in the twentieth century, in which the electromagnetic, weak nuclear, and strong nuclear forces were unified at the very high energies of the very beginning of the Big Bang. Unlike ordinary magnets, which always possess both a north and a south pole, a monopole would be a particle carrying an isolated magnetic charge, either north or south.

– **The flatness problem:** why is space so vast, so old, and so geometrically flat (Euclidean space)?

– **The horizon problem:** how can the temperature of the cosmic microwave background be virtually identical in regions of space that have never been in causal contact?

– **The problem of the origin of primordial fluctuations:** what is the origin of the primordial fluctuations from which all the structure of matter has grown?[105]

A theory became established in the nineteen eighties and nineties: inflation[106]. Inflation is a rapid expansion of space, diluting monopoles and other relics, making space flat and uniform like the surface of an inflating balloon, and transforming quantum fluctuations of the vacuum into macroscopically significant density fluctuations, capable of seeding the formation of galaxies.

Inflation, initially described within the framework of the Big Bang for a particular universe—ours—has become a multiversal theory by considering inflation as a general phenomenon, giving rise to a global inflationary multiverse (eternal chaotic inflation). Our universe is only one of the infinitely many bubbles in this global inflationary system.

In the global inflationary process, one inflationary bubble generates others, which in turn produce others, in an endless chain reaction. Each of these bubbles is infinite in size, yet there exists an infinity of them, since the chain reaction never stops. Indeed, if this exponential growth in the number of bubbles has lasted forever, there will exist an uncountable infinity of parallel universes of this kind.

[105] It is a matter of explaining the origin of the density fluctuations observed in the cosmic microwave background, which served as the seeds for the formation of galaxies and large-scale cosmic structures (clusters and superclusters).

[106] Guth, Steinhardt, 1984 ; Linde, 1984.

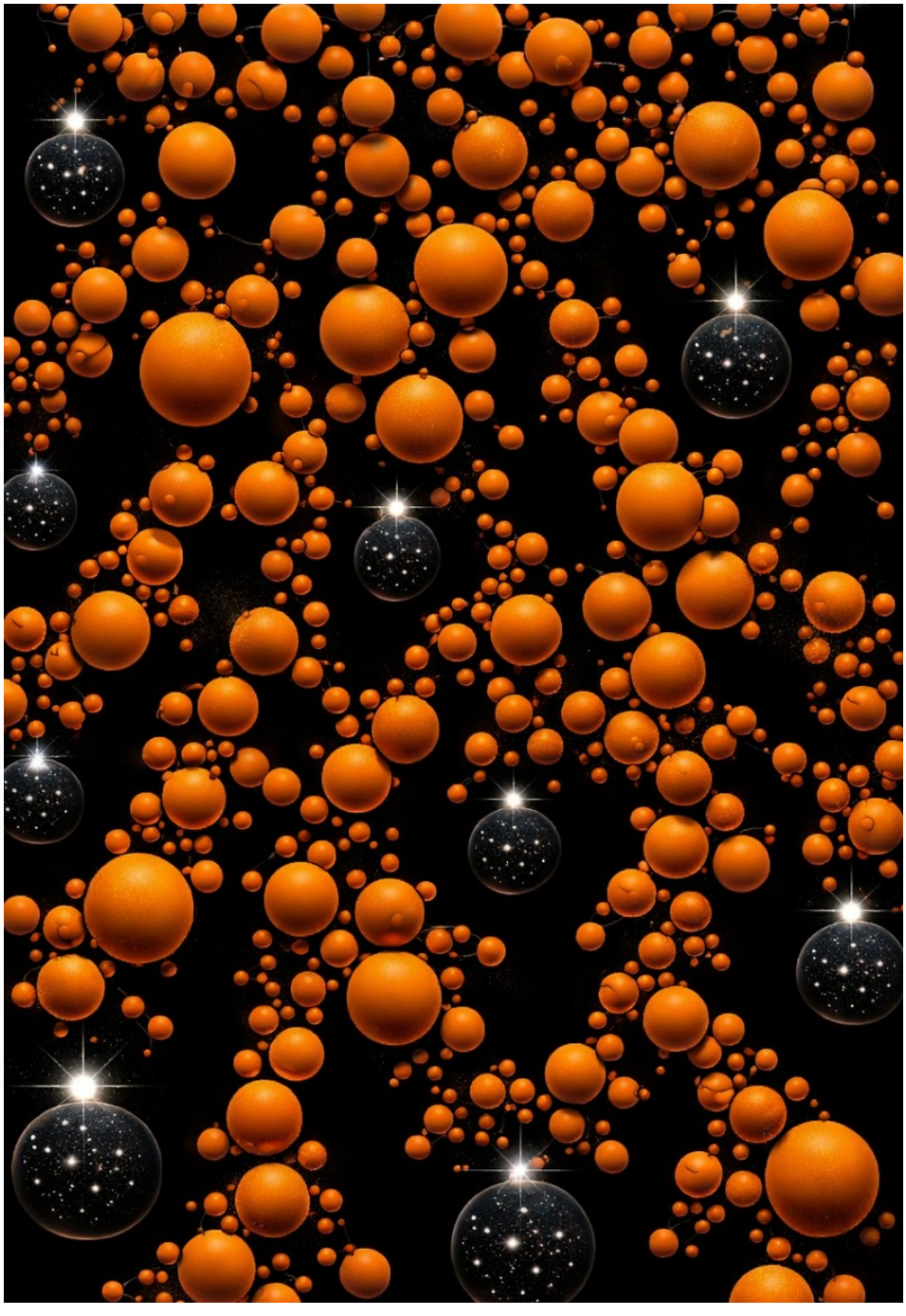

**Figure 35** Artist's representation of the Type 2 inflationary multiverse. Energy inflation unfolds randomly, exponentially, and indefinitely (red bubbles). It may cease here and there, thereby forming one of the Big Bang universes capable of hosting biology and consciousness on a planet. We are in one of these universes.

A phenomenal universe arises when inflation ends in certain regions of space, the energy of the inflationary field being converted into particles and radiation. Matter and the fundamental interactions then unfold, allowing, under the effect of gravitation, the formation of large cosmic structures: galaxies, stars, planets, with the possible emergence of biology and consciousness. The bubbles in which inflation has stopped thus constitute the elements of the type 3 multiverse.

**The type 3 multiverse**

The ontological status is that of a spatial multiverse, corresponding to the infinite extension of a post-inflationary universe. It corresponds to the multiplicity of observable regions within a given universe. The mode of variation is a variation of spatial position. It is the multiverse that corresponds to the current, standard cosmological model. It is consistent with all observations: an immense universe, which may be infinite, beyond our cosmic horizon (the observable universe). It is this spatial multiverse that led Giordano Bruno[107] to be condemned to the stake in 1600.

We have seen that the universe has gradually expanded in scale over the centuries, following observational and scientific advances. In the nineteen twenties and thirties, it already measured 200 million billion billion kilometers in diameter, according to Edwin Hubble. Today, the lower bound of the total universe is estimated at 87 thousand billion billion kilometers in diameter, that is, about 100 times that of the so-called "observable" universe. But in a practically flat, Euclidean space, why not instead consider the total universe as infinite? And in an infinite space, how can one not conceive of an infinity of spheres of observable space? A spatially infinite universe is what the theory of cosmic inflation predicts[108]. And, to transpose a famous remark, if spatial regions—what are called observable

[107] Bruno, 1995. Philosopher, mathematician, and astronomer, he continues the work of Nicholas of Cusa and Nicolaus Copernicus. He develops a theory of heliocentrism and attempts to demonstrate, in a philosophical way, the existence of an infinite universe without center or circumference, populated by an "innumerable quantity of stars and worlds identical to our own."

[108] Garriga, Vilenkin, 2001b.

universes, limited by the cosmic horizon—were not infinite in number to fill infinity, "iIt would be a terrible waste of space."[109]

The universe is not only possibly infinite: on large scales, it is remarkably uniform. Wherever we look, we observe galaxies grouped into clusters and superclusters[110].

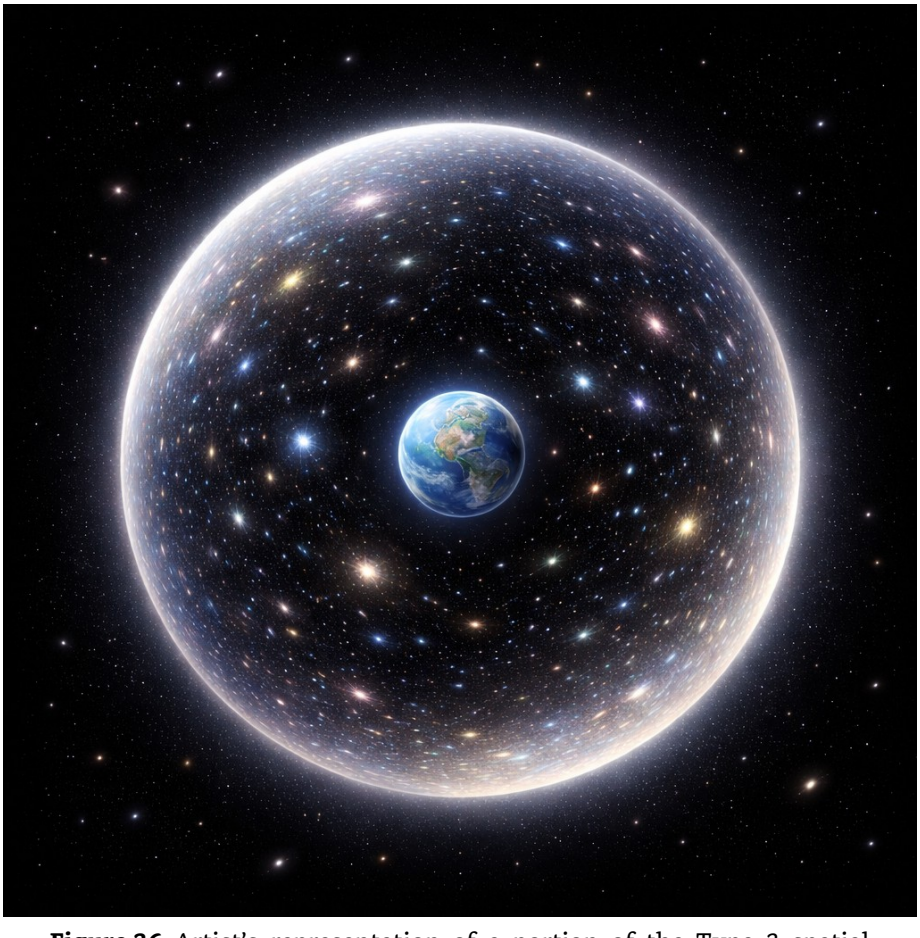

**Figure 36** Artist's representation of a portion of the Type 3 spatial multiverse. Here is depicted one of the infinitely many "regions" of this spatial multiverse. "Spatial" means that the regions belong to the space of a single Big Bang universe arising from cosmic inflation.

[109] A line spoken by Jodie Foster, whose character is referring to the possibility that extraterrestrials may exist in the universe, in the film *Contact*, directed by Robert Zemeckis.

[110] For example, the Laniakea Supercluster, which encompasses the Virgo Supercluster to which the Milky Way belongs.

However, three-dimensional surveys of their distribution show that these spectacular structures fade when one changes scale: beyond about one thousand billion billion kilometers, the apparent organization gives way to statistical homogeneity, without larger coherent structures. Measurements of the cosmic microwave background confirm that this uniformity extends to the limits of the observable universe. "Space as we know it extends far beyond the limits of our observable universe, teeming with galaxies, stars, and planets."[111]

These initial conditions include the densities, velocities, and distribution of the components of matter, components that originate from the quantum fluctuations that occurred during the inflationary phase. This process generates a spectrum of nearly random fluctuations, described mathematically as an *ergodic* random field. Ergodicity[112] means that the statistical distribution obtained by comparing many volumes within a single universe is identical to that which would be obtained by considering a set of distinct universes endowed with different initial conditions. In other words, everything that is physically possible here is realized elsewhere.

Inflation thus assigns a nonzero probability to all initial configurations compatible with the laws, which are then amplified by gravitational instability to form galaxies, stars, and planets. All imaginable configurations of matter therefore occur somewhere in sufficiently distant Hubble volumes. By the principle of typicality, our own volume must be statistically ordinary among those that host observers. Estimates suggest that an identical copy of us would be located at a distance on the order of $10^{10^{29}}$ meters.

If multiple copies of "me" exist, sharing the same past and the same memories, nothing allows me to know which one I truly am, each experiencing the same sense of identity. Their trajectories will nevertheless eventually diverge; from that point on, I can only make probabilistic predictions about what I will experience. Max Tegmark concludes that this undermines the traditional conception of scientific determinism.

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[111] Tegmark, 2004.

[112] For example, the numbers of stars, galaxies, clusters, and superclusters within a given volume.

However, this point of view is debatable. For each of these copies of "me" remains subject to the laws of cause and effect. And the very fact, for each "me," of performing the action that consists in "reasoning in probabilistic terms" also proceeds from causal chains (thinking and predicting what is probable do not occur without causes).

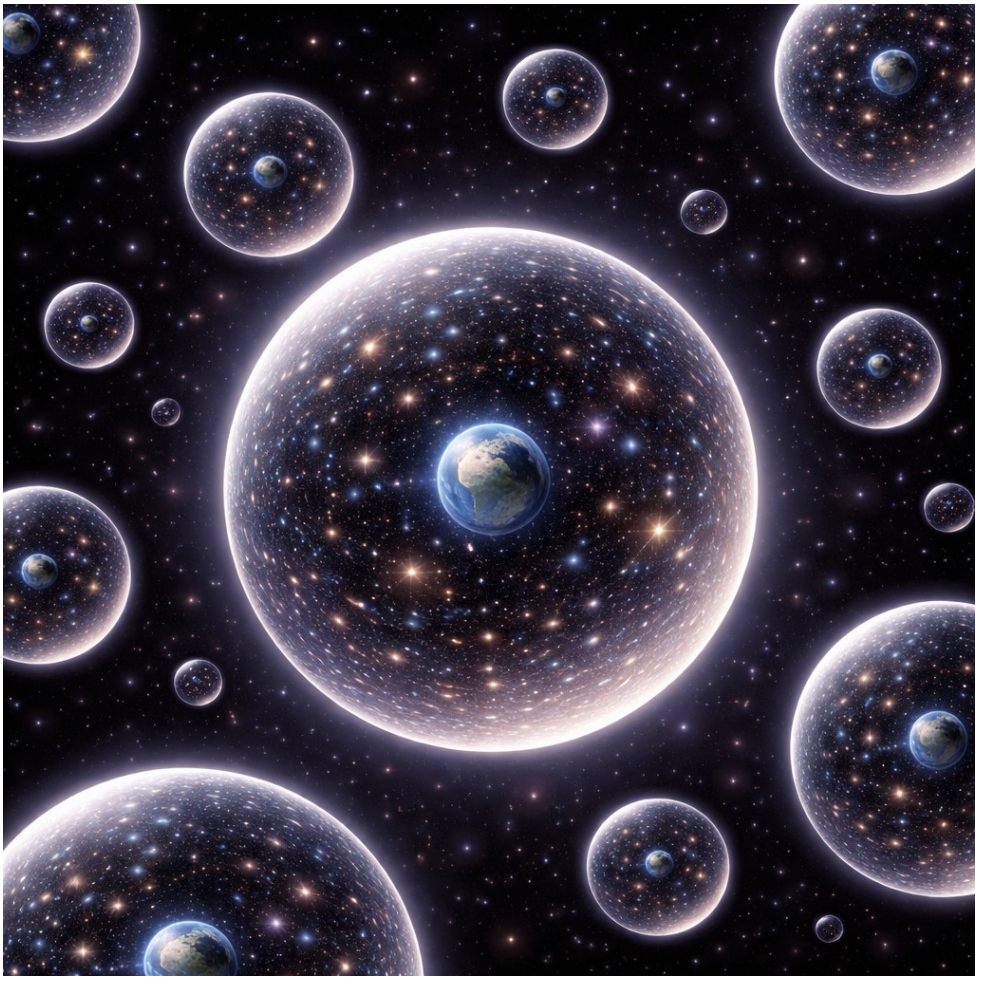

**Figure 37** Artist's representation of the Type 3 spatial multiverse. In an infinite Big Bang universe, there exists an infinity of "regions," each corresponding to an observable universe (the cosmological horizon). An identical copy of the reader most likely exists in another region, at a distance on the order of $10^{10^{29}}$ meters.

If several copies of me possess a strictly identical past, each then following a different trajectory, it becomes impossible to know

which one I am. This impossibility does not stem from a breakdown of causality, but from a problem of self-location: I do not know my position within the whole. The indeterminacy is therefore indexical and epistemic, not physical. Each trajectory is determined, but I can only predict the probability of finding myself in one or another.

Thus, what the multiverse undermines is not the determinism of the laws, but the intuitive idea that a given past corresponds to a single lived future. If determinism is defined as the phenomenal uniqueness of the personal future, then yes, this uniqueness disappears. But if determinism is understood to mean that the state of the world, at a given moment, fully determines its evolution according to laws, then the type 3 multiverse does not contradict it. It even radicalizes it, since all possibilities compatible with the equations are actually realized.

The tension concerns less causality than personal identity: what does "me" mean when there exist multiple equally legitimate continuations of the same past? It is not physics that wavers, but our existential representation of the uniqueness of becoming.

One can estimate that the nearest identical copy of us is located at a distance of about $10^{10^{29}}$ meters. At a distance of about $10^{10^{91}}$ meters, there should exist a sphere with a radius of 100 light-years identical to the one centered here, such that all the perceptions we will have over the next century will be identical to those of our counterparts there. At a distance of $10^{10^{115}}$ meters, there should exist an entire Hubble volume identical to ours. This is an estimate obtained simply by counting all the possible quantum states that a Hubble volume can have without exceeding a temperature of $10^8$ K. Each of these $10^{115}$ locations can be either occupied or unoccupied, which gives $2^{10^{115}}$ possibilities. This number can be written as an extremely large power of 10, which can be noted $10^{10^{115}}$ at the scale of orders of magnitude considered here[113].

The type 3 multiverse serves as a standard operational framework for testing contemporary cosmological models. Thus, measurements of the cosmic microwave background indicate a nearly flat spatial geometry, which rules out an open universe model. This quasi-Euclidean flatness is attributed to the model as a whole, including the infinity of Hubble volumes it contains, although observations of

[113] All these numerical estimates are from Tegmark, 2004.

the cosmic microwave background directly concern only our own volume.

**The type 4 multiverse**

Its ontological status is that of a modal quantum block multiverse (the many-worlds interpretation of Everett). It refers to the multiplicity of coexisting versions of the same world. The mode of variation is a variation of state.

If one considers the fact that the fundamental equations of quantum mechanics describe a superposition that does not collapse, then it appears that the universe (ours, the spatial universe) branches into parallel universes each time a quantum event seems to have a random outcome. All possible outcomes actually occur, one in each "branch" of these parallel universes. This is the type 4 multiverse (also called "Everett's many worlds").

Quantum mechanics revolutionized physics by explaining the atomic world. Its applications are numerous and accompany the accuracy of its predictions: chemistry, nuclear reactions, lasers, semiconductors… Without quantum mechanics, no computers, no smartphones, no journey to the Moon.

Yet, a full understanding of quantum mechanics is not straightforward. It gives rise rather to "interpretations," which concern the mathematical object called the *wave function*. The Schrödinger equation tells us that this wave function evolves over time according to a superposition model.

Concretely, if we imagine a particle described by a wave function, this function gives the probabilities of finding it here or there. The Schrödinger equation describes how this *probability wave* changes over time. Superposed evolution means two things: (1) the total probability always remains equal to 100% (if one adds up all the possible chances of finding the particle somewhere, one always obtains 100%)[114]; (2) the evolution is continuous and fully determined (if one knows exactly the state of the particle at a given

[114] In probability, a result is always between 0% and 100%. A probability of 0% means that an event is impossible, while a probability of 100% means that it is certain. Intermediate values indicate the degree of likelihood of the event: the closer the value is to 100%, the more probable the event; the closer it is to 0%, the less probable it is.

moment, the equations unambiguously determine what this state will be a moment later).

It is like a wave on the surface of water: its shape changes, it deforms, interferes, propagates, but there is no abrupt jump. It evolves smoothly according to precise rules. The same is true for a quantum particle: its wave function propagates, deforms, and interferes in the space of possibilities without ever abruptly "choosing" a position or a particular state as long as no measurement interaction occurs.

**Figure 38** Artist's representation of the Type 4 modal multiverse. Our two famous young women stand at the branching point of two Everettian multiverse paths, symbolized by the rearview mirrors. They face a choice: the police pursue them and they plunge into the Grand Canyon; or they turn back to surrender to the authorities, leaving the precipice behind them.

This space of possible states is what is called in mathematics a *Hilbert space*. It is an abstract mathematical space in which, for each quantum state, the wave function is nothing other than the representation of that state of the particle. For example, the representation of positions or that of momenta, of velocity. As long as there is no measurement (as long as there is no detection of the

particle), the wave function can remain in a superposition concerning the state of the particle. For example, the particle is "here and there" at the same time.

Superposed evolution does not choose between "here" or "there"; it evolves the superposition itself. The problematic aspect appears only when one speaks of measurement, because the measured result is unique, whereas superposed evolution does not eliminate any possibility. Likewise, the particle can be described as having several possible momenta at the same time, the wave function simultaneously containing different momentum values that can interfere with each other.

If one adopts Everett's many-worlds interpretation, the particle, which is "here and there," encounters a detector, but instead of obtaining either: (A) "particle here + detector indicating here," or (B) "particle there + detector indicating there," the situation remains superposed, (A) and (B) coexist in the global state of the particle + detector system. However, the system then evolves into two autonomous branches: (A) "particle and detector here" and (B) "particle and detector there." From the point of view of the global state, nothing has disappeared: (A) and (B) coexist as two distinct branches of univers, rendered independent by a process called *decoherence*.

Two important remarks: (1) each branch corresponds to a global state of the universe, not only to a local region; (2) the branching does not concern only the particle and the detector, but all the systems correlated by the interaction. This includes internal consequences within the device (for example the triggering of a "cat trap"), a computer or video record, and even the brain state of a human observer who perceives the result[115] and, ultimately, the entire universe.

At present, experimental devices test the loss of coherence, not only with particles—for example, billions of electrons in a

[115] The systematic and abusive replacement, in magazines or popular science documentaries, of the terms "detector" by "observer," or "detect," "measure" by "observe," has fueled the persistent myth of the influence of thought on matter and on particles, giving rise to an entire quantum mysticism. And no! The observer's thought has no influence on matter, not even on a particle.

superconducting device (qubits)—but also with packets of thousands of atoms. Nothing in these results provides direct access to real "branches" of parallel universes. No experiment allows one to decide between "there are truly multiple worlds" and "there is only one." But the theory describes things as if multiple possibilities coexist[116].

The type 4 multiverse adds nothing new compared to type 2 and type 3 multiverses. Theoretically, it consists only of additional and indistinguishable copies of the same universes, the same scenarios repeating endlessly in other quantum branches.

The type 4 multiverse implies that there are different ways in which certain situations can occur. It corresponds to the superposition of an infinite set of quantum states, all being different temporal translations of the same state, such that a Big Bang occurs at different moments in different quantum branches. All possible snapshots of the universe exist at every moment. It follows that the passage of time is only an illusion, a matter of perception[117].

**CONCLUSION**

The table (next page) shows the nesting of the four multiverses that constitute the totality of what is. This nesting logic consists, starting from the bottom, of a type 4 multiverse embedded within a type 3 multiverse, both embedded within a type 2 multiverse, the whole embedded within a type 1 multiverse, each multiverse being infinite. It should be noted that, in a synthetic reading of the table, the further one moves down from 1 to 4, the more the framework remains stable and the more variation is restricted. Initially structural, it becomes parametric, then configurational, and finally merely event-based.

[116] Tegmark, Wheeler, 2001.

[117] An idea explored in the science fiction novel by Greg Egan (1996), *Permutation City*, and developed by David Deutsch (1997), Julian Barbour (2001), and others.

**Figure 39** Free artist's representation of the nesting of the four multiverses in a setting that is, quite evidently, Mayan ritualistic.

It should be noted that this table clearly shows the articulation from one multiverse to another, but also the limited set of characteristics of each multiverse that it transmits to the subsequent ones. Thus, it is important to specify that, beyond the characteristics present in this table, other characteristics are absent. These are what might be called "exotic" characteristics, including universes marked, for example, by illogicality, contradiction, incoherence, and which might additionally possess a baroque geometry. In a single epithet, multiverses with **impossible** universes. The possible then becomes the characteristic of Being, of what is, and the impossible becomes the sign of nothingness, of what is not.

Ernst G. Straus recounts that, during a discussion on fundamental laws, Albert Einstein is said to have formulated his question as follows: "What really interests me is whether God had any choice in the creation of the world."[118] The meaning of this question is not theological, but epistemological: Einstein is asking about the degree of necessity of physical laws.

[118] Straus, 1979.

**Nesting of the four multiverses**

**Type 1 multiverse — Mathematical**

**What lies at the base:** the internal logical consistency of each structure; the axioms specific to the structure under consideration; the formal identity of this structure.

**What varies across structures:** the fundamental laws themselves; the form of the equations; the constants; dimensionality; the metric signature; the global topology; the nature of the fundamental objects; the existence or non-existence of time; the very type of dynamics.

**Comment:** a variation of structure that determines multiverses 2, 3, and 4. The mathematical architecture changes. The other multiverses are then internal subsets within certain particular structures.

**Type 2 multiverse — Eternal global inflationary**

**What remains unchanged:** the meta-theoretical framework (general relativity or equivalent, quantum mechanics, the inflationary field, the principle of expansion); the global mathematical structure.

**What changes:** the effective constants; the coupling parameters; the field content; the broken symmetries; possibly the effective dimensionality; the local thermal history; the possible topology of the bubbles.

**Comment:** a variation of parameters within a single inflationary theory. The bubbles are different solutions of the same system of equations.

**Type 3 multiverse — Post-inflationary spatial**

**What remains unchanged:** the fundamental equations and laws; the constants; local physics; the prior inflationary structure; the relativistic-quantum framework.

**What changes:** the local initial conditions; the configurations of matter; contingent realizations (the distribution of galaxies, the trajectories of objects in space, local histories).

**Comment:** a variation of states within a single infinite global universe. Repetition of the same and multiplication of the possible through spatial extension.

**Type 4 multiverse — Modal quantum block**

**What remains unchanged:** the characteristics are identical to type 3, but physics follows a superposed evolution.

**What changes:** the outcomes of quantum processes; the branch decompositions; the macroscopic configurations resulting from decoherence.

**Comment:** a variation of outcomes within a single global state. The branches do not differ by their laws, but by the actualization of the amplitudes of the wave function.

Are the constants, the equations, the very structure of the fundamental interactions constrained by a deep logical coherence, or could they have been different? In other words, is there a single mathematically consistent theory describing reality, or a space of possible theories?

Let us imagine a completely fanciful universe, arising from a highly exotic multiverse, and thus deemed impossible. Suppose a geometry shaped like Mickey Mouse, with eighteen spatial dimensions, two temporal dimensions, no inflation, with a totally strange relativity law, gravity becoming levitation and light zigzagging at only 342.123456789 kilometers per hour (well, when there are hours!). And this universe belongs to a non-inflationary type 2 multiverse. Thus, it stands alone, emerging from an equally fanciful type 1 multiverse, in which mathematical equations are replaced by an infinity of toons[119]. From this emerge Mickey Mouse, Goofy, Donald Duck, Pluto, Bugs Bunny, Tweety, and various Tom and Jerry universes… with their misshapen galaxies, stars, and planets, the latter inhabited by beings capable of defying the semblances of physical laws, allowing them to be immortal, with elastic, indestructible bodies, able to duplicate themselves into dozens of copies, to appear in several places at once, to fall from great heights and survive, to pass through walls (leaving only a hole in the shape of their silhouette), to survive explosions and flattenings, to breathe underwater and in the vacuum of space, to conjure objects out of nothing, and so on.

Neither Blanqui, nor Lewis, nor Einstein, nor Newton envisioned such a universe. Universes therefore obey an implicit law of good convention, of tradition, of classicism. Here, we deal only with the possible: "We do the possible immediately; the impossible takes a little longer." We are therefore necessarily limited in what we can imagine of universes and multiverses.

Any coherence imposes formal constraints. The possible requires a complete absence of fantasy. The universe must march in step, hair neatly parted on the right, uniform impeccable, one, two, one, two… An inflationary universe is not freely imaginable: it must be the solution of a consistent system of equations, typically a relativistic field theory coupled to gravitation. The dynamics of inflation

[119] Cartoon characters.

presuppose an evolution compatible with the equations. Not all arbitrary combinations of parameters or geometries are admissible: many would lead to instabilities, to uncontrolled divergences, or to the absence of any solution at all, thus to nothingness, to "this does not exist."

In other words, mathematical consistency acts as a filter. In the type 2 multiverse, variation occurs within a given inflationary framework: only configurations compatible with this theory exist as possible bubbles. One cannot insert just any geometric or dynamical fantasy if it is not a solution of the equations of the inflationary framework. Likewise, in the type 1 multiverse, the constraint shifts scale: one is no longer limited by a particular theory, but only by the internal logical consistency of a mathematical structure. The freedom is greater, but it remains bounded by the absence of contradiction. The impossible still lurks.

Without going as far as the extremes of a toons multiverse, can one, for example, envisage a global inflation limited to three bubbles? Within the standard framework of eternal chaotic inflation[120], the answer is no. Eternal inflation rests precisely on the fact that some regions continue to expand while others "drop out" by forming bubbles. The total volume undergoing inflation grows faster than the volume exiting it: statistically, the production of bubbles therefore never stops. One thus obtains an infinity of bubbles.

A scenario with exactly three bubbles would require that global inflation ceases everywhere after a finite number of transitions. This is no longer eternal inflation in the technical sense. It would be a finite inflation, globally halted, producing a limited number of domains. This type of model is conceivable in theory, but it does not correspond to the mechanism of exponential self-reproduction that defines present-day physics.

Here one clearly sees that, when one stretches theoretical elastic bands more or less too far, a formalism and a coherence reveal themselves as necessities for things to work. There is no need even to invoke an anthropic principle. The anthropic hits us in the face! Even modal logic, limited to "possible worlds" in the sense of David Lewis, appears constrained within a kind of cosmic scholasticism.

[120] Linde, 1994 ; Tegmark, 2004.

The more one stretches the possible, the more formal constraint reappears. One believes one is opening up the space of universes, and one discovers that it is structured by very stringent conditions of existence: stability of solutions, coherence of fields, existence of bound states, regularity of the equations. We have not even spoken of observers, and already mathematics imposes a drastic filter. The weak anthropic principle becomes almost trivial: only domains compatible with complex structures are actually inhabited. There is no need to add a teleological principle; selection follows from the equations themselves.

As for modal logic in the sense of David Lewis, it appears, at first glance, infinitely liberal (all possible worlds exist), yet it remains inexorably subject to consistency. A contradictory world is not possible. Even modal realism is therefore bounded by a minimal ontological grammar. One may multiply worlds, but one cannot abolish coherence.

The previous table shows the architecture of what is; what follows will unfold its thickness. For a universe is not reducible to its constants, its equations, or its branches: it also carries, at times, chemistry, biology, self-organized complexity, and, in certain restricted domains, consciousness. The question is therefore no longer only that of possible structures, but of structures capable of producing organisms, nervous systems, lived worlds. What we call "Omnivers" will then have to integrate this rise in complexity as an internal property of certain regions, without adding anything to the laws, but by exploring their consequences up to the emergence of the gaze cast upon them.

Finally remains the more vertiginous hypothesis: what if the whole itself obeyed a recursive structure? What if each multiverse, nested within the previous one, were only a level of an even more vast organization, analogous to a fractal figure in which the same logical pattern is reproduced at different scales? This Omnivers would no longer be merely the totality of coherent universes, but a fractal architecture of nested blocks, an ontological geometry where the repetition of the same and the multiplication of the possible are indefinitely intertwined. This would then form an infinite hierarchical fabric, stable in its principles, varied in its realizations, and perhaps conscious in some of its folds.

Part Five

# THE OMNIVERSE

# 1. From fractals to inflation

In classical geometry, the notion of dimension is simple and intuitive. A line has dimension 1: one can move along it only in a single direction, as if following a narrow path along a mountainside. A surface has dimension 2: length and width, like the surface of a football field that one can traverse in all directions. A volume has dimension 3: length, width, height, like a gymnasium where one climbs a rope net. Newtonian space is precisely this three-dimensional space, homogeneous and continuous, in which objects occupy a volume and move according to the laws of mechanics. The dimensions are whole, clear, stable: 1, 2, 3.

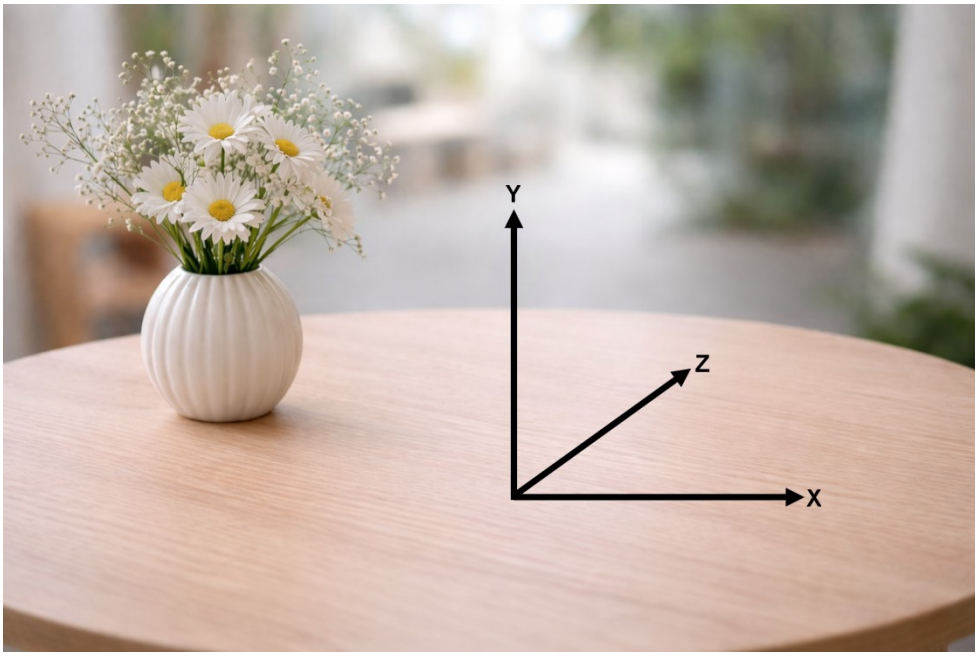


**Figure 40** The concept of dimensions in classical geometry is simple to understand and corresponds to our everyday experience.

Fractals introduce a disturbing idea: a dimension that is no longer an integer. An object can be "slightly less than a line," or "more than a line" without being a surface, or "more than a surface" without being a full volume. Its dimension becomes fractional. It is simply written D = a non-integer (decimal) number. This number measures the

extent to which the object fills space. The larger D is, the denser the object is in the space it inhabits. For example, the Cantor set. It is constructed by endlessly removing the middle third of a segment. What remains is an infinite dust of points. It is no longer a continuous line (dimension 1), but neither is it a simple discrete set. Its dimension is D = 0.630929753. It occupies “more than nothing,” but “less than a line.”

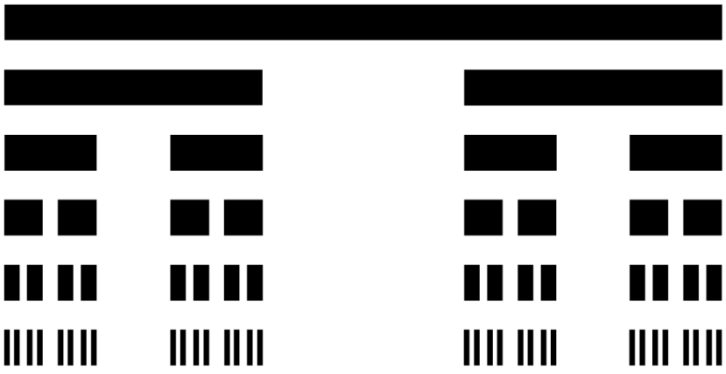

**Figure 41** The Cantor set, for D = 0.630929753.

Another example is the Koch curve. It begins with a segment whose each portion is replaced by four smaller segments. At each step, the length increases without bound, but the object remains contained within a finite region. Its dimension is D = 1.261859507. It is more complex than an ordinary line (D = 1), without becoming a surface (D = 2).

The Sierpiński triangle, for its part, is constructed by endlessly removing the central triangle from a larger subdivided triangle. It gradually transforms into an infinitely perforated planar lace. Its dimension is D = 1.584962501. It fills the plane more than a simple curve, without reaching the fullness of a surface.

A final example is the Menger sponge. It is the three-dimensional analogue of the Cantor set: cubes are endlessly removed from the center of an initial cube. The object becomes infinitely perforated. Its dimension is D = 2.726833028. It is more than a complex surface, but less than a full volume.

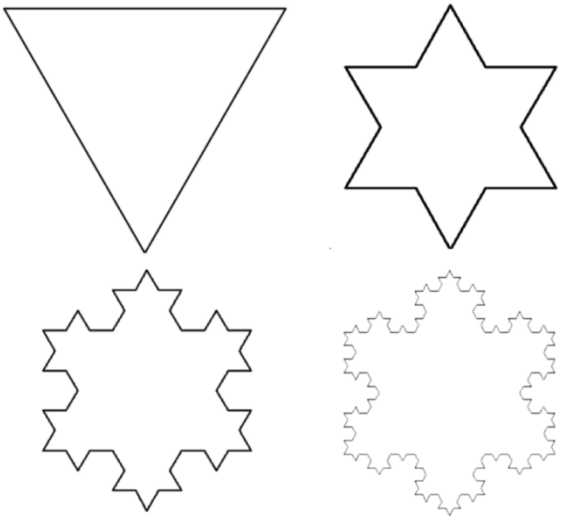

**Figure 42** The Koch curve, for D = 1.261859507.

**Figure 43** The Sierpiński triangle, for D = 1.584962501.

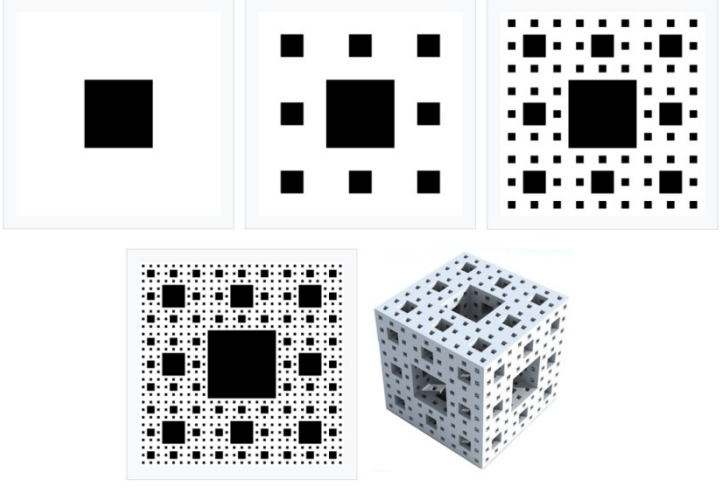

**Figure 44** The Menger sponge, for D = 2.726833028.

These examples are mathematical, strictly self-similar: the same structure repeats at all scales, indefinitely. In nature, one observes approximate fractal forms (branching patterns, roughness, networks), but only over a limited range of scales.

As for the cosmos, the question has been raised: does the distribution of galaxies form a fractal on large scales? Current observations indicate that it does not. On small scales (clusters, filaments, voids), matter exhibits a hierarchical and irregular structure, without being fractal. But on very large scales, the Universe becomes statistically homogeneous: the effective dimension tends toward 3 (the Euclidean, so-called "flat," infinite space of our everyday experience). In other words, there is no global cosmic fractal in the observable Universe. There are hierarchical structures in the Universe, but not an infinite fractal of non-integer dimension filling the cosmos.

Within the framework of eternal inflation, the idea of fractality does not appear as a strictly demonstrated mathematical result, but as a geometric property suggested by the very dynamics of the mechanism. In Alexander Vilenkin[121], the exponential expansion of the false vacuum does not stop everywhere at once. Regions "thermalize"[122] and give rise to bubble universes, while others continue to expand. This process repeats indefinitely: as some regions cease expanding, the total volume still undergoing inflation grows faster than it disappears. The result is an extremely irregular structure, in which pockets of universes form within a background in permanent expansion. The boundary between expanding regions and thermalized regions becomes increasingly intricate as time goes on. Vilenkin then invokes a fractal-type geometry to describe this hierarchical entanglement, without proposing a calculated dimension or a detailed formalism.

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[121] Vilenkin, 1983a.

[122] In inflationary cosmology, one speaks of thermalization when a region ceases to be dominated by the quasi-constant energy of the inflaton field (see the following note), when this field decays into ordinary particles, and when vacuum energy is converted into radiation and matter. This phase corresponds to a reheating: the local universe becomes a dense, hot plasma, analogous to that of the standard Big Bang model. A "bubble" that thermalizes is therefore a region where inflation has ended and where classical cosmological evolution begins.

In Andrei Linde[123], the scenario of chaotic, or self-reproducing, inflation radicalizes this picture. Quantum fluctuations of the inflaton[124] field cause certain regions to climb the potential locally instead of descending it, thereby indefinitely prolonging inflation in these domains. The global universe then becomes a set of thermalized islands embedded in an ocean of inflation, itself in perpetual expansion. Linde explicitly speaks of a fractal structure of the "whole," in the sense of a hierarchy without a single characteristic scale, arising from a recursive process of self-reproduction. Here again, it is a strong geometric analogy: the spatial distribution of expanding and post-inflationary domains exhibits statistical self-similarity, but the precise fractal dimension is not the central focus of the analysis.

In these foundational works, fractality is thus a structuring idea: it expresses the fact that the inflationary mechanism does not produce a simple collection of juxtaposed bubbles, but an intertwined spatial branching, in which each region can generate other regions according to the same dynamics. It is not a fractal "within" an already given universe; it is an emergent geometry of the inflationary multiverse itself, conceived as an endless process. In other words, there is no global cosmic fractal in the observable universe. Observations of the cosmic microwave background (space missions COBE, WMAP, and Planck) and galaxy surveys confirm this homogeneity on very large scales.

Thus, if the observable universe is not a fractal, the eternal inflationary framework suggests a fractalization of the cosmic "whole," not in the galaxies, but in the very genesis of domains of universes. It is this geometric sketch that will need to be developed further when it comes to thinking an omniversal fractal.

[123] Linde, 1990.

[124] The inflaton refers to the hypothetical field responsible for the primordial phase of cosmic inflation. It is the potential energy associated with this field that is thought to have driven the exponential expansion of space.

# 2. The Omniversal Fractal

Terminological clarification: by "Omniverse" we indeed mean the set of the four nested multiverses: mathematical, inflationary, spatial, and modal.

**From hierarchy to fractal**

Beyond Andrei Linde and Alexander Vilenkin, there have been no further developments of fractalized inflation. No major conceptual revolution. The "fractality" of eternal inflation is not a fundamental principle posited at the outset, but a simple geometric consequence of the self-reproduction mechanism.

In the 1990s and 2000s, the question of probabilities in eternal inflation made it possible to refine the global structure of the inflationary universe, which remains hierarchical, with a set of thermalized domains embedded within an expanding background. Some works[125] have explicitly calculated the fractal dimension of the set of regions still undergoing inflation, showing that it is less than 3. Fractality then becomes a technical object, linked to volume measures, rather than a simple metaphor. Here again, the mechanism of transitions by bubble nucleation in an exponentially expanding space produces a branching structure, statistically self-similar. Fractality is implicit in the dynamics of the landscape, but rarely highlighted as a central theme.

More recently, researches[126] has focused mainly on observational consistency (constraints from the cosmic microwave background measured in particular by the Planck spacecraft), on the stability of inflationary models, and on questions of measure and predictability. The idea of a fractal structure of the inflationary multiverse has not been abandoned, but it has not led to a fully formalized autonomous geometric theory either. It remains a robust consequence of the eternal inflation scenario: if the self-reproduction process is correct, the global geometry is hierarchical and fractal in nature.

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[125] Vilenkin, 1982.

[126] Winitzki, 2002; Guth, 2007.

Thus, envisaging an omniversal fractal is of a different order. Such a fractal does not concern the spatial texture of a single inflationary multiverse, but the ontological nesting of the levels themselves, a structural recursivity between multiverses of all types. One may then speak of a meta-structural fractality, as the repetition of the pattern "stable framework + internal variation" at different logical scales, rather than a simple geometric self-similarity in three-dimensional space.

A "stable framework," means a set of rules or structures that do not vary within a given level (physical laws, space-time, constants, mathematical structure, etc.). Within this framework, there exists an internal variation (different initial states, different configurations of matter, quantum fluctuations, effective parameters, bifurcations and Everettian many worlds). The "repetition of the pattern," in the omniversal fractal, therefore means that at each level one finds the same logical architecture: a relatively invariant container that allows a plurality of internal realizations. It is not a self-similarity of forms in space, but a self-similarity of conceptual structures.

In other words, the inflationary literature provides here a partial analogy, but not a direct foundation. To go further, we must formalize the recursivity of multiverses of block universes as a property of stable inclusion at each level, independently of inflation alone. This theoretical procedure is not forbidden by current physics; it is simply not yet an established model.

The infinite set of inflationary bubbles, infinite in number and infinite in size, together with the bubbles that have emerged as Big Bangs and structured universes, forms a fractal block. A block in which there is no beginning, no flow, and no end of time. The Big Bangs of inflationary universes are like explosions[127] frozen in a snapshot. This global inflationary block is therefore composed of an infinity of expanding bubbles and post-inflationary regions similar to the one we inhabit, forming overall a fractal structure. As a reminder, the study of the cosmic microwave background shows that there is no fractalization within a type 3 multiverse, that is, at the level of spatial regions infinite in number— within our universe. Spatial universes can thus be regarded as repetitive units within the fractal.

[127] "Explosion" is used here as a metaphor. Big Bangs are not explosions.

**Fractal: how it works**

Within the framework of an omniversal fractal, the fractal unit must not be sought in a simple geometric form (such as, for example, the Koch triangle), but in an ontologically complete block. We shall therefore define the unit as the bubble-universe arising from the type 2 inflationary multiverse, understood not as a simple spatial domain, but as an integrally thermalized spacetime block.

Within the framework of the omniverse, the fractal unit is therefore not just any bubble arising from eternal inflation, but specifically a bubble that has left the inflationary expansion regime in order to enter a phase of thermalization, that is, a Big Bang-type universe. Eternal inflation generates a branching tree of expanding domains, but only some subdomains see vacuum energy converted into particles and radiation, stabilizing constants and initiating a classical cosmological dynamics. It is these thermalized bubbles, complete spacetime blocks endowed with an internal history, that we shall retain as fractal units.

This bubble-universe includes: a determined set of physical constants, a content of fields and particles stabilized after local inflation, its own cosmological dynamics (expansion, gravitational structuring, entropy), an ergodic spatial extension (repetition of the same and multiplication of the possible) belonging to type 3, and quantum modal branching belonging to type 4. It thus constitutes a coherent and self-sufficient subset from the physical point of view. The omniversal fractal unit is therefore not a point, nor a region, but a complete block capable of generating within itself the repetition of the same and the multiplication of the possible. It generates nested structures: spatially through ergodic repetition and modally through decoherence.

At the higher scale, an infinity of such bubbles (the bubbles that are expanding and those that thermalize) is itself included within a distinct type 1 mathematical structure among an infinity of other possible structures.

Thus defined, the thermalized type 2 bubble-universe becomes the elementary building block of the omniversal fractal: a block capable of being found again, under parametric or structural variations, across an infinity of mathematical realizations.

The method of deployment from the unit is as follows: a complete inflationary bubble-universe, a thermalized spacetime block containing within itself levels 3 and 4. Fractalization then consists not in copying it mechanically, but in recursively applying the same logic of inclusion at each level.

**Step 1:** Internal deployment ($2 \supseteq 3 \supseteq 4$)[128]. Inside the bubble (type 2), spatial ergodicity (type 3) realizes the repetition of the same and the multiplication of the possible: in a sufficiently vast space, all configurations compatible with the local laws are realized. Inside each region, unitary quantum dynamics generates modal branching (type 4): each event indeterminate from the classical point of view corresponds to a coexistence of branches. The bubble therefore already contains an internal branching structure.

**Step 2:** Inflationary replication (2 again). The regime of eternal inflation produces other bubbles, each with its own possibly distinct parameters (constants, symmetry breaking, field content). Each new bubble reproduces the $2 \supseteq 3 \supseteq 4$ structure. Self-similarity appears here: one unit generates structurally analogous units.

**Step 3:** Mathematical variation ($1 \supseteq 2$). Each coherent set of inflationary bubbles is included within a given mathematical structure (type 1). But there exists an infinity of distinct mathematical structures. For each one, if conditions allow, an analogous inflationary hierarchy may exist. Fractalization then reaches its highest level: not only repetition of bubbles within one structure, but repetition of structures containing hierarchies of bubbles.

The general method is therefore as follows: identify a complete unit; make its internal nested structure explicit; show that this structure can be reproduced at a higher level through parameter variation; then conceptually iterate this inclusion up to the mathematical level. As a reminder, self-similarity never applies to geometric form, but to the rule of generation: the inclusion of sets

[128] The symbol $\supseteq$ (inclusion) here denotes a hierarchical nesting relation: a type 1 multiverse contains type 2 multiverses, which themselves contain type 3 multiverses, which in turn contain type 4 multiverses. It does not express an order of magnitude or value, but a relation of inclusion between levels of structure.

that themselves contain hierarchically ordered sets according to the scheme 1 ⊇ 2 ⊇ 3 ⊇ 4.

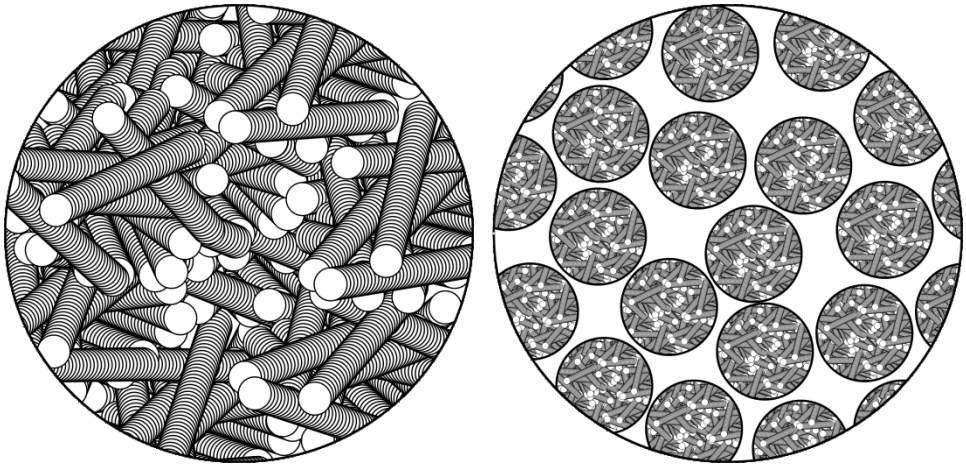

**Figure 45** On the left, a Type 4 modal quantum multiverse, Everettian in nature, containing the multiplicity of coexisting versions of a single world, as required by quantum hypotheses. On the right, a Type 3 spatial multiverse, containing an infinity of "regions" (Hubble volumes or observable universes), resulting from the spatial extension of a single post-inflationary universe and implying the statistical repetition of material configurations.

The omniversal fractal is thus nothing other than the recursive repetition of the same ontological nesting rule, applied to variable contents.

### The complete picture of the omniversal fractal

In the form of a "block," as in "block universe," and thus outside any temporality (time being only one of the dimensions within some of these units), the omniversal fractal contains the entire temporal fabric—past, present, and future—of the omniverse.

In the foreground, occupying almost the entire surface, are the type 1 blocks, representing mathematical structures in infinite number. They are not arranged in a grid, but distributed like "cores," each autonomous, each defining a complete logical framework. Each type 1 core gives rise within itself to a region of internal expansion corresponding to type 2. Visually, these can be represented as regions emanating from each mathematical block.

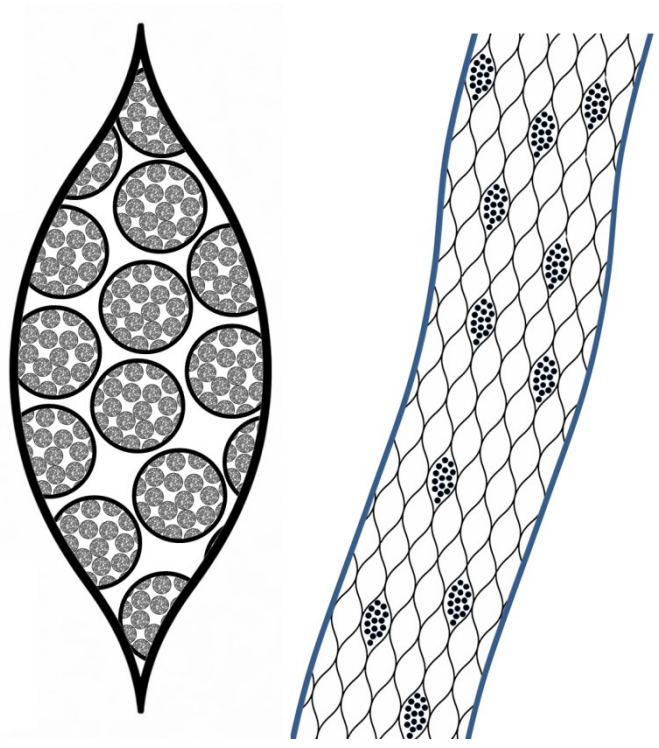

**Figure 46** On the left, a Type 2 global inflationary multiverse, containing the multiplicity of spatial multiverses, as required by the hypotheses of eternal chaotic inflation. On the right, a Type 1 mathematical multiverse, encompassing the infinity of inflationary universes and required for the conjecture of contiguous universes (see below).

Within these regions appear the type 2 blocks, corresponding to inflationary regimes. Their dynamics are branching. Bubbles detach from the inflationary background in infinite number. Most remain simple expanding domains, but some undergo thermalization. These are the ones that become visually denser in the picture, forming more distinct, more contrasted substructures.

Each thermalized bubble constitutes a type 3 block, that is, a spatial universe initiated by a Big Bang and an internal phase of inflation. Inside, the surface becomes granular. Spatial ergodicity (the repetition of the same and the multiplication of the possible) produces a repetition of configurations. The pattern becomes more refined, as when zooming in and discovering more and more detail. The picture suggests this repetition through a recurring internal texture.

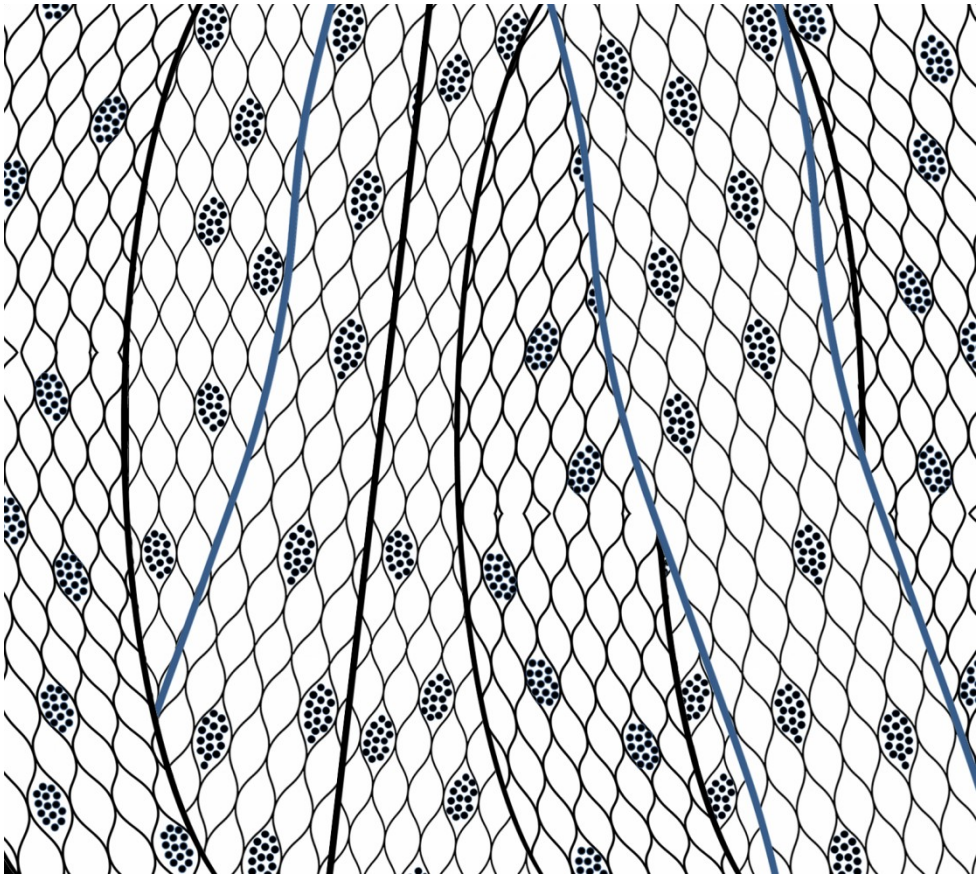

**Figure 47** Representation of an infinite fractal omniverse (or omniversal fractal), composed of the entirety of the structures of the mathematical multiverse.

Finally, within each spatial region, the structure subdivides further into type 4 blocks. These are no longer geometric expansions, but modal branching in chains. Visually, this corresponds to translucent micro-branchings, layered rather than spread out, suggesting an internal proliferation rather than an external expansion.

The overall picture gives the impression of a deployment in depth: columns of mathematical structures (type 1), inflationary branching structures (type 2), structured thermalized spheres (type 3), and finally fine modal subdivisions (type 4). Self-similarity does not lie in a repeated form, but in the principle: each level generates an internal multiplicity that becomes the support for the next level.

**The final touch**

How can one experience the thought experiment of being inside the omniversal fractal? To do so, we turn again to Laplace's demoness. Let us imagine that we encounter Laplace's demoness who, using her extraordinary superpower, will serve as our cosmic guide within the omniversal fractal itself. Carried along by the demoness, what will we see?

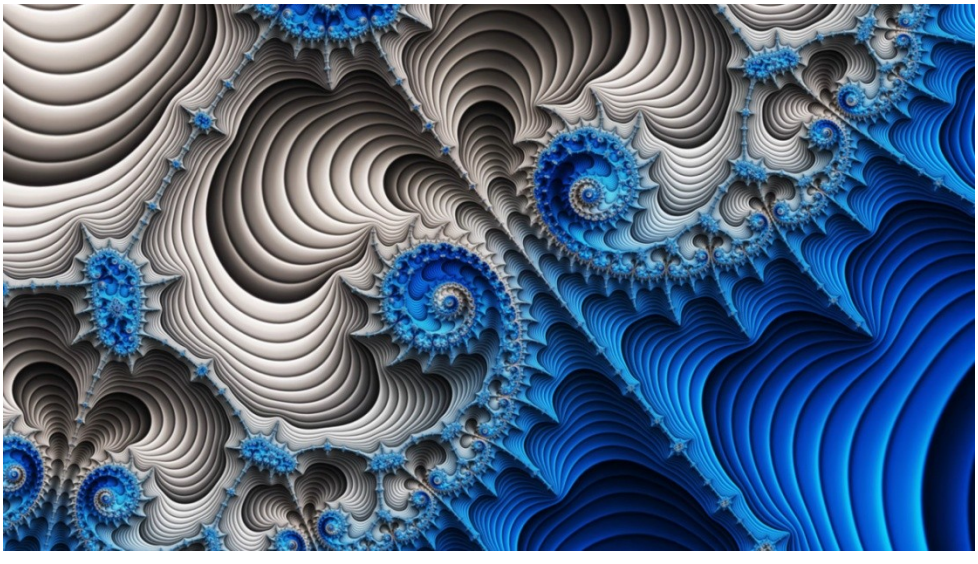

**Figure 48** A screenshot of the fractal video "Sapphires".

To visually render this picture of the omniversal generative fractal, exploring all possibilities, we will draw inspiration from one of the "Sapphires"[129] fractal videos, in particular the one referenced in the note, a variant of a Mandelbrot set producing bluish rosette-like structures, self-similar, with repeating fan-shaped patterns. A complex fractal, obtained through iteration in the complex plane, where a central motif replicates at different scales with local distortions, yet with a recognizable overall signature.

We do not claim a strict isomorphism between the omniversal fractal and what unfolds in this video. It should simply be seen as a source of visual inspiration. One may, for example, at second 23 of

[129] The interested reader can find the fractal video that inspired us here: https://youtu.be/8cgp2WNNKmQ. Copyrights Olbaid ST (https://bit.ly/3ZUgApy) et Maths Town (https://bit.ly/46rV6E1).

the video, imagine the large grey bulges as type 1 multiverses. As the demoness draws us deeper into the omniversal fractal, we move into increasingly repetitive configurations. At second 55, within type 1, type 2 multiverses appear in layers, sapphire-colored, their bubbles stacking infinitely. It then remains only to imagine, within each sapphire bulge (at 1 minute and 6 seconds, for example), a type 3 multiverse, then a type 4 multiverse, and a galaxy called the Milky Way, and a planet called Earth, and ourselves, somewhere on that planet—and perhaps we may feel the vertigo of being somewhere within this infinite omniversal fractal…

In summary, if the omniversal fractal is conceived as a compact stacking of fully constituted blocks—mathematical structures giving rise to inflationary regimes, thermalized bubbles, spatial universes, and modal branching—then nothing requires these blocks to be strongly isolated. Their contiguity becomes conceivable: not as ordinary communication between universes, but as topological adjacency within a dense global architecture.

In such a configuration, two or more universes, adjacent within the block, might not be absolutely sealed off from one another. Their contiguity would not reduce to simple geometric proximity, but would refer to a structural closeness capable of allowing weak influences, residual correlations, or boundary effects at the limits of their respective domains.

The conjecture of contiguous universes thus emerges from this compact omniversal fractal vision: a dense omniverse in which blocks are not separated by an ontological void, but juxtaposed within a higher continuity, such that certain interactions, not attributable to an internal source, could originate from influences emanating from contiguous universes.

### The conjecture of contiguous universes

Since the end of the twentieth century, observational cosmology has revealed a deep asymmetry between what we see and what the equations require. The rotation speeds of galaxies, the dynamics of clusters, and the effects of gravitational lensing reveal an excess of gravity that visible matter alone cannot account for. To explain this surplus, so-called “dark” matter is introduced: not directly observed, but inferred as the dominant gravitational component.

To this enigma is added another, even more unsettling. The study of distant supernovae and of the cosmic microwave background indicates that the expansion of the universe is not only ongoing, but accelerating. A component with negative pressure, referred to as "dark" energy, is then postulated to account for this acceleration.

Moreover, within the inflationary framework, dark matter and dark energy are not late additions, but components integrated into the overall evolution originating from the primordial inflationary phase. Inflation sets the initial conditions: near spatial flatness, an almost scale-invariant spectrum of fluctuations, and the distribution of structure seeds. After thermalization and the era of radiation domination, dark matter (assumed to be cold and weakly interacting) amplifies, through gravitational instability, the initial fluctuations produced during inflation, allowing the hierarchical formation of halos[130] and galaxies. It is thus consistent with the inflationary scenario, whose initial conditions it exploits.

As for dark energy, within the inflationary framework, one must distinguish two phases of accelerated expansion separated by the thermal and gravitational history of the universe. The first phase, primordial inflation, occurs extremely early, between about $10^{-36}$ and $10^{-33}$ seconds, expanding the universe by a factor of $10^{26}$, just after the Big Bang. It is attributed to the potential energy of a very high-energy scalar field and explains the near spatial flatness as well as the spectrum of initial fluctuations. After thermalization, the universe enters eras dominated first by radiation and then by matter. Much later, when the density of matter diluted by expansion becomes lower than that of a negative-pressure component, a second phase of acceleration appears: the one currently attributed to dark energy, often modeled by a cosmological constant $\Lambda$ or by a very low-energy scalar field (vacuum energy). Thus, primordial inflation and late-time acceleration are two distinct regimes of accelerated expansion, framing an evolution dominated by dark matter, while the inflationary model does not yet specify the microscopic nature of these two components.

[130] Gravitationally bound structures, dominated by dark matter, that form through the amplification of primordial fluctuations after inflation and during the matter-dominated era.

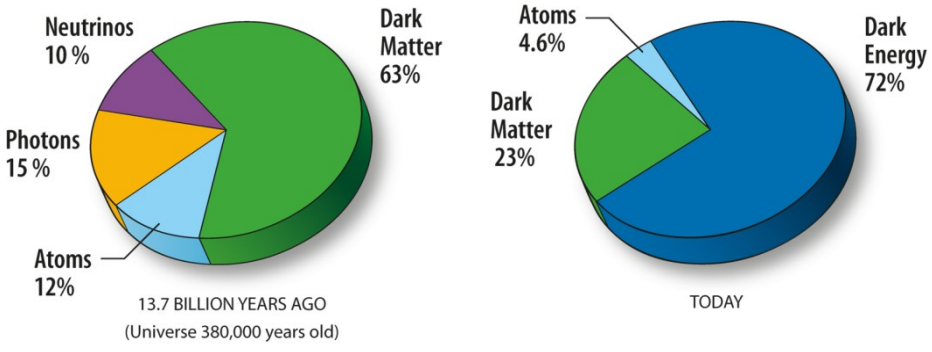


**Figure 49** Compositions of the Universe in fundamental elements, including the hypothetical dark matter and dark energy, at 380,000 years after the Big Bang and today.

In the standard cosmological model, these two components account for most of the energy content of the cosmos (dark energy $\approx$ 72%; dark matter $\approx$ 23%), while ordinary matter (stars, gas, planets) makes up only a minor fraction ($\approx$ 4.6%). Contemporary cosmology thus rests on entities defined primarily by their dynamical effects rather than by direct observation. The qualifiers "dark" do not describe their nature, but rather reflect, almost poetically, our ignorance. The question is no longer only to measure the universe, but to identify the true nature of what governs its evolution.

It is here that the conjecture of contiguous universes proposes to replace this ignorance with an external causality, arising from the fractal neighborhood of blocks. To this end, the conjecture advances five hypotheses:

**(1) Fractal contiguity hypothesis:** our universe is embedded in a full, fractal omniverse-block, leading to proximity and contact between universes.

**(2) Absence hypothesis:** there are no particles corresponding to dark matter; there is no field corresponding to dark energy.

**(3) Inter-universe effects hypothesis:** excess gravitation and the expansion of space are consequences of the presence of universes contiguous to our own.

**(4) Horizon contact hypothesis:** there is an inter-geometric influence between contiguous universes.

**(5) Gravitational influence hypothesis:** contiguous universes can produce nucleation[131] sites of apparent matter.

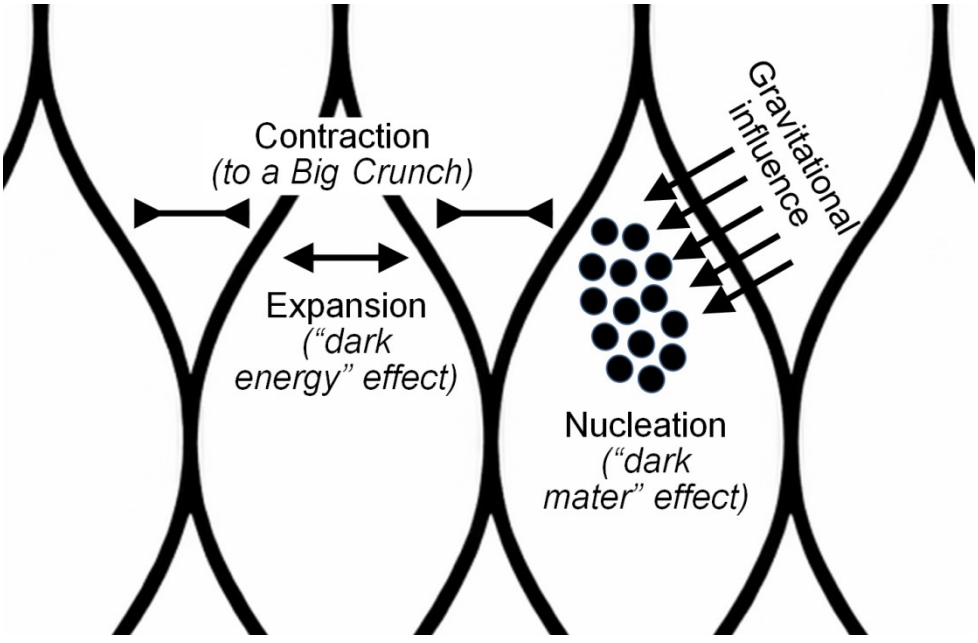


**Figure 50** Diagram illustrating the conjecture of contiguous inflationary universes. On the left, the hypothetical links between contracting universes and an expanding universe, through a geometric effect; on the right, the gravitational influence of one universe on another, through nucleation ("dark matter" effect), as a first step toward matter–energy–gravitation.

Thus formulated, the conjecture of contiguous universes operates an ontological shift: instead of postulating new entities internal to our block (dark matter particles or a dark energy field), it attributes the observed effects to an external causality arising from the fractal neighborhood of other block universes in geometric contact with ours. If such inter-universe influences, in particular gravitational ones, were indeed able to account for the signatures currently attributed to dark matter and dark energy, then these would cease to

[131] By analogy, the term "nucleation" is borrowed from the physics of phase transitions: a system can remain homogeneous for a long time (supercooled liquid, supersaturated solution) until the appearance of a seed triggers the formation of bubbles, crystals, or a new phase; this is referred to as nucleation.

be “substances” and would become interface effects. In this sense, explaining dynamical anomalies and cosmic acceleration through inter-geometric interactions would, in return, constitute an indirect but powerful argument in favor of the actual existence of a fractal omniverse: multiverses would no longer be a speculative extrapolation, but the minimal explanatory condition for the phenomena measured within our own universe.

## CONCLUSION

All scientific authors [132] who address the question of the multiverse are careful to point out that the universes composing it, beyond their genesis, are separated from one another and exhibit a kind of logical and physical impermeability preventing any passage from one universe to another (with the exception of the Everettian modal multiverse). The conjecture of contiguous universes does not claim otherwise and only posits inter-universal influences, both geometrical and gravitational. From there, one may wonder what the interface between two contiguous universes would look like. Is it an invisible wall? A kind of mist? A doorway in space? Or nothing at all, just a simple sign warning that beyond this boundary you are changing universes. In any case, the question of the interface remains open.

The omniversal fractal is not merely a descriptive motif added to contemporary cosmology; it proposes a comprehensive reformulation. By shifting from a hierarchy of structures to a fractal organization of blocks, the omniverse ceases to be a juxtaposition of levels and becomes instead a geometry of ontological inclusions, where each universe is both a local totality and a fragment of a larger structure.

[132] One finds as many scientists defending the multiverse thesis (Lee Smolin, Don Page, Brian Greene, Max Tegmark, Alan Guth, Andrei Linde, Michio Kaku, David Deutsch, Leonard Susskind, Alexander Vilenkin, Yasunori Nomura, Raj Pathria, Laura Mersini-Houghton, Neil deGrasse Tyson, Sean Carroll, Stephen Hawking) as there are expressing skepticism about it (Sabine Hossenfelder, David Gross, Paul Steinhardt, Anna Ijjas, Abraham Loeb, David Spergel, Neil Turok, Viatcheslav Mukhanov, Michael S. Turner, Roger Penrose, George Ellis, Joe Silk, Carlo Rovelli, Adam Frank, Marcelo Gleiser, Jim Baggott, Paul Davies).

**Figure 51** How might one conceive of the boundary between two contiguous universes? Perhaps quite simply with a touch of humor. Suddenly, a road sign appears, at the far reaches of a deep Hubble universe. A staircase in the style of Maurits Cornelis Escher perfectly symbolizing the relativity of this invisible boundary. So, watch your step!

The complete picture reveals its internal coherence: repetition of the same, multiplication of the possible, nesting of physical frameworks, and variation of parameters no longer stand in opposition, but are distributed according to a logic of self-similarity.

The final touch, with the conjecture of contiguous universes, introduces a minimal dynamic principle within the fractal block itself: the effects attributed to dark matter and dark energy could arise from interface interactions between adjacent geometries. If

such a perspective were to prove fruitful, it would transform a speculative architecture into an explanatory requirement, turning the omniversal fractal from a metaphysical image into a framework capable of absorbing the current enigmas of cosmology. And perhaps, in return, provide us with empirically testable evidence of the presence of universes contiguous to our own.

Part Six

# FROM ENTROPY TO CONSCIOUSNESS

# 1. Biology and consciousness

The Fermi[133] paradox emerged in 1950 from a simple question: if the universe contains hundreds of billions of stars in the Milky Way alone, a significant fraction of which have planets, and if physical and chemical processes are universal, then the emergence of life (and later of technological civilizations) should not be a unique event.

Even assuming modest expansion speeds, a civilization capable of interstellar travel could colonize the galaxy in a short time on cosmological scales—just a few million years. Yet we observe no artifacts, no probes, no unambiguous signals. The question attributed to Enrico Fermi ("Where are they?") thus crystallizes this contradiction between expected probability and observed silence.

The proposed answers fall into three broad categories. Either intelligent life is extraordinarily rare: one of the steps, biological or cultural, constitutes a "great filter," almost impossible to pass. Or civilizations are frequent but short-lived, destroying themselves or losing interest in expansion. Or, finally, they exist but remain undetectable: because of distance, deliberate discretion, communication modes incompatible with our instruments, or simple coexistence without perceptible interaction. The paradox proves nothing. It maps out a zone of ignorance at the interface between astrophysics, evolutionary biology, and the sociology of civilizations.

Frank Drake[134] formulated the equation that bears his name in 1961, initiating the scientific search for extraterrestrial signals. He was one of the founders of the SETI (Search for Extraterrestrial Intelligence) program and led Project Ozma, the first modern attempt to detect artificial radio signals from nearby stars.

His equation was not intended to produce a reliable number, but to structure the problem into distinct factors, transforming a speculative question (how many communicating civilizations are there in the Milky Way?) into a quantifiable research framework.

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[133] Physicist, awarded the Nobel Prize in Physics in 1938.

[134] Radio astronomer.

Drake also played a central role in the design of the Arecibo message in 1974, a symbolic attempt at interstellar communication.

The value of the Drake equation is methodological: it makes the unknowns explicit, situates orders of magnitude, and stimulates observation. At the time, several terms in the equation were almost entirely speculative. Since then, the massive discovery of exoplanets has constrained the first factors, while the biological and sociotechnical terms remain open. The Drake equation thus functions more as a research program than as a calculation, linking astrophysics and evolutionary contingency within a single multiplicative structure.

The variety of physical parameters within the framework of eternal chaotic inflation, producing the type 2 multiverse, may determine whether life—and possibly consciousness [135] —can emerge. A few examples: the mass of a star, which can range from $10^{29}$ to $10^{32}$ kg. Yet the very narrow range that allows life on a planet orbiting such a star limits the stellar mass (a Sun-like star) to between $1.6 \times 10^{30}$ kg and $2.4 \times 10^{30}$ kg, making possible a planet that is neither too hot (like Venus) nor too cold (like Mars). One must of course also take into account the orbital distance of the planet, neither too close (Venus) nor too far (Mars). Another example: if the electromagnetic force were weakened by just 4%, stars (including the Sun) would explode immediately. If it were stronger, there would be fewer stable atoms, which would likewise prevent the formation of stars.

Other examples of parameters that can significantly affect atomic stability include the possibility of ejecting heavy elements from a forming star (nova), and the presence of ordered structures such as crystals and DNA molecules. From this point on, the biological possibilities within a type 2 multiverse depend on factors such as: at the atomic level, a weak interaction that is more or less strong; a proton mass that is higher or lower; protons that are more or less massive; a proton-to-electron mass ratio that is higher or lower, affecting stellar stability. All these parameters, which influence low-energy physics, must be finely tuned to a certain degree to allow—or

[135] The reader will have understood that we are not concerned with extraterrestrials "as such," but with the possibility of conscious life beyond humans in the universe.

prevent—the emergence of biological systems on possible planets, thereby differentiating the various universes within the type 2 inflationary multiverse.

Moreover, in a Big Bang model, the emergence of galaxies, stars, and their planets concerns only a more or less limited fraction of space within this Big Bang universe, before it undergoes either an infinite expansion leading to the dissolution of all atoms (eternal expansion), or a recontraction toward a Big Crunch. There is therefore only a relatively short cosmological window during which biology may emerge, if the parameters of the universe allow it.

It should also be kept in mind that, even in a universe where all parameters are finely tuned to allow life, the emergence of life depends on many additional, more local parameters, specific to the configuration of a given planetary system. Depending on the system, biology and conscious life may depend, as we have seen, on the planet's orbit, more or less close to its star. But also on the presence of a moon orbiting the planet.

If we consider the example of Earth, the presence of a massive moon acts at several dynamical and geophysical levels. First, the stabilization of Earth's obliquity: without the gravitational torque exerted by the Moon on the equatorial bulge, Earth's rotation axis would be far more sensitive to planetary perturbations, especially those of Jupiter, leading to chaotic variations in tilt that could induce extreme climate regimes. A relatively stable obliquity limits large-scale thermal excursions and favors the long-term continuity of ecological niches.

Next, tides. Lunar tidal forcing produces regular cycles of flooding and drying in coastal regions. These physicochemical gradients, with periodic concentration of solutes, are often invoked in prebiotic scenarios as environments conducive to polymerization and compartmentalization[136]. Even though alternatives exist (such as deep hydrothermal vents), tides provide an efficient mechanism for contact, mixing, and chemical selection in continental surface environments.

[136] Two essential processes in scenarios for the emergence of life. Polymerization corresponds to the assembly of small organic molecules into longer chains. Compartmentalization refers to the formation of structures that define an internal environment distinct from the external one.

The Moon has also contributed to the rotational evolution of Earth: tidal braking has gradually lengthened the duration of the day. An initially very rapid rotation, resulting from the giant impact, slowed toward periods compatible with less extreme thermal cycles and a more stable atmospheric dynamics. Finally, the impact that formed the Moon likely contributed to Earth's internal differentiation, to the formation of a massive metallic core, and thus to the existence of a long-lasting magnetic field, protecting the surface from the solar wind and atmospheric erosion. Our natural satellite can slightly deflect or intercept some bodies, although its protective role against impacts remains limited. The Moon is therefore not a demonstrated necessary condition for life, but it combines several stabilizing effects that may facilitate its emergence and persistence.

**Where to locate consciousness?**

Since the seventeenth century, a major philosophical tradition has held that consciousness cannot be reduced to material processes. Its classical formulation is given by René Descartes [137], who distinguishes two irreducible substances: *res extensa*, that is, matter extended in space, and *res cogitans*, the thinking substance. Within this dualist framework, mind or consciousness has a nature different from that of the physical world and therefore cannot be explained by the laws of matter. This ontological separation between mind and body has deeply shaped Western philosophy and can be found, in various forms, in many later spiritualist or idealist approaches. Despite advances in the brain sciences, this line of thought persists today among certain philosophers or theorists of mind[138], who hold that subjective experience—lived consciousness—cannot be fully derived from material mechanisms.

Unlike "spiritualists" in the Cartesian sense, nothing in principle prevents extending reflection on the "hard problem" of

[137] Descartes, 1984.

[138] Henri Bergson, Thomas Nagel, Colin McGinn, Galen Strawson, and Jean-Luc Marion, without necessarily endorsing a strict Cartesian dualism, maintain that consciousness has a dimension irreducible to purely material descriptions.

consciousness [139] into fundamental physics and cosmology. However, doing so changes the very nature of the problem.

A first approach is to suppose that physical laws contain, at a level not yet perceived, variables or structures linked to conscious experience. Consciousness would no longer be a local emergent product, but a property correlated with certain organizations of matter, inscribed in the ontological fabric of the world. In this case, cosmology sets the global conditions of possibility: fundamental constants, the structure of spacetime, the dynamics of information. These approaches to the problem of consciousness are primarily philosophical and physico-metaphysical rather than empirical. David Chalmers, for example, explicitly proposes that conscious experience be treated as a fundamental property, on a par with mass or charge, within a framework of "fundamental psychophysics." Likewise, Philip Goff[140] argues that consciousness is a fundamental and ubiquitous property of the physical world. For Alfred North Whitehead[141], each "occasion of experience" has both a physical pole and an experiential pole, embedding proto-experience within the very structure of reality. Galen Strawson[142], finally, defends a form of physicalism that includes conscious experience as a fundamental constituent of matter.

On the physico-cosmological side, Roger Penrose[143] advances the hypothesis of a link between consciousness and the fundamental structure of quantum gravity. John Archibald Wheeler[144], for his part, suggests that the informational structure of the cosmos is constitutive of physical reality itself. His phrase "it from bit" means that physical entities (particles, fields, spacetime) ultimately derive from elementary informational acts, that is, binary answers arising from measurement-like interactions. In other words, it is not "things" that are primary, but events of registration, binary distinctions 1/0 that actualize properties. Matter, geometry, and even laws thus emerge from a fundamental network of

[139] Chalmers, 1995, 2010.

[140] Goff, 2019.

[141] Whitehead, 1995.

[142] Strawson, 2006.

[143] Penrose, 1992, 1995.

[144] Wheeler, 1990.

informational acts. Finally, in an explicitly cosmological vein, Max Tegmark[145] identifies reality with a mathematical structure. If conscious experience exists, it must then correspond to an internal property of certain structures.

These authors do not converge on a single theory, but together form the conceptual background for the idea that consciousness might be rooted in fundamental physics and, by extension, in cosmology.

A second approach explores the idea that consciousness depends on deep informational properties (a structure of Hilbert space, quantum decoherence, integrated complexity), thereby indirectly linking the problem to quantum physics and the global structure of the cosmos. This does not resolve the explanatory gap, but reframes it as a question of informational architecture permitted by fundamental laws, drawing on quantum physics, information theory, and formal theories of consciousness.

For Giulio Tononi[146], consciousness corresponds to an intrinsic causal informational structure characterized by a formal quantity of information generated by the system. In integrated information theory, consciousness is precisely this intrinsic causal structure. Again, Max Tegmark[147] proposes that certain physical states, described in Hilbert space, possess specific informational properties associated with conscious experience. Roger Penrose and Stuart Hameroff put forward the so-called "Orch-OR" (Orchestrated Objective Reduction) hypothesis. Quantum superpositions would occur in neuronal microtubules[148], whose structure would allow for transient quantum coherence. Successive objective reductions would constitute elementary proto-experiential events, and their neuronal organization would give rise to conscious states[149].

The question of conscious biology beyond Earth first encounters a brute fact: silence. Despite the efforts of Frank Drake and early programs such as SETI or Ozma, no signal, no trace, no artifact has

[145] Tegmark, 2014.

[146] Tononi, 2008.

[147] Tegmark, 2015.

[148] Neuronal microtubules are microscopic hollow tubes found in neurons. Among other functions, they are involved in intracellular transport.

[149] Hameroff, Penrose, 2014.

broken the observational void. Yet the conditions for the emergence of life have been analyzed with increasing precision, from the earliest cosmological parameters (inflation, fundamental constants, structure of primordial fluctuations) to the physicochemical constraints of a temperate planet analogous to Earth. The required fine-tuning appears narrow, and it is indeed realized here, for us; but why it is realized remains unanswered.

At this point, some shift the question toward the relationship between matter and consciousness. If life is rare, consciousness would be even rarer; if it exists, it must be rooted in the organization of reality. Theories proliferate: integrated information, causal architectures, Hilbert spaces, decoherence, neuronal microtubules. The names are illustrious, the formalisms sophisticated. Yet bringing together consciousness and matter, consciousness and cosmos, proves as resistant as trying to mix oil and water. The concept of information sheds light on structures and measures correlations, but it does not eliminate the gap between organization and phenomenality. Even quantum physics is invoked to give thought a fundamental grounding. René Descartes would no doubt be amused to see his "pineal gland"[150] replaced by neuronal microtubules.

But perhaps the impasse stems from a presupposition. We are looking for consciousness as a thing in the world, whereas we are already within a block universe of which it is a part. If the cosmos is a complete spacetime block, consciousness does not arise within it as an additional ontological layer: it constitutes one worldline among others. It creates neither time nor motion. It seems rather to "read" or "scan" them, giving the global structure the appearance of flow. The "hard problem" then changes its form: it becomes a problem of anthropocentrism. What importance should be granted to a neural structure that, on a cosmological scale, lasts only a few decades for an individual, a few hundred thousand years for humanity, in a universe whose history spans billions of years between the Big Bang and its thermal fate?

[150] Within the framework of his mind-body dualism, René Descartes indeed located the seat of consciousness in this brain gland, the only one not to exhibit right-left bilateral symmetry.

Thus, consciousness, far from being a cosmic center, appears as a local modulation within the geometry of the block. Perhaps we should stop trying to pin it down as an entity and instead understand it as an internal effect of this global structure, a mode of reading embedded in inflationary dynamics and in the increasing complexity of matter. The “hard problem” does not disappear; it shifts. It is no longer a matter of explaining how matter produces experience, but of understanding how, within an already given universe, certain worldlines take the form of an illusion of presence and flow.

# 2. Consciousness and entropy

If, at first glance, consciousness appears to us as an elusive phenomenon giving rise to many speculations, a reflection on the articulation between the block universe and neurobiology may save us from the "hard problem" it seems to pose for many authors. The rescue expedition will first take us to the cosmic stage where everything unfolds. We will then articulate the links between consciousness and entropy, which will ultimately lead us to the myth of consciousness—not as a solution to the hard problem, but as a way of moving beyond it.

**Excursion with the demoness**

Warning! Thought experiment. Laplace's demoness invites us to visit the block omniverse, slice by slice, in her company. So, let's go! Let us leave the world of flowing phenomena, step outside the block, and re-enter it—this time as amateur "demons," accompanied by a demoness. First impression: everything is motionless, frozen. An empty space, yet we can feel that it is filled… with energy!

"What's it?"

"The vacuum energy,"[151] the demoness tells us.

"But we don't see anything?"

Then suddenly, in the next slice, we see a tiny swelling appear, a bulge, like a minute ripple in the vacuum.

"Look!" says the demoness, "that's the first bubble about to emerge from the vacuum. This is only the beginning!"

The ripple begins to expand and, indeed, it becomes a bubble.

"Where does it come from? Why this primordial bubble? What's it made of?" Questions rush in.

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[151] A clarification: in quantum field theory, the "vacuum" of vacuum energy is not a void, but the ground state of a field, which possesses a nonzero minimal energy due to quantum fluctuations. It is not an exploitable energy nor a hidden reservoir, but a property of the field formalism, whose possible macroscopic effect is discussed in cosmology through the cosmological constant. Sorry, YouTube dreamers!

"I'm gonna tell you the whole story," says the demoness. "Let's pause for a moment, just before what comes next."

And the demoness, with a slightly mysterious air, as if sharing a secret, begins to tell the story.

"Once upon a time, there were five knights: Proton, Neutron, Electron, Photon, and Neutrino, colliding… frenetically! That, my dears, is the primordial furnace."

"Oh, really?!" we say.

"Yes!" she continues. "Later, this story became a myth, with its dark energy and its inflaton… Careful!" the demoness warns us. "It's about to blow!"

From the primordial bubble, another bubble escapes, then another, and another still. Then from these bubbles, more bubbles appear, in chains and clusters. It reminds us of expanding foam used to insulate a house. And the further we go with the demoness, the more the slices of the block omniverse extend to infinity, filled with bubbles in infinite number, forming block multiverses infinite in number.

We wonder: "But how do all these bubbles form? It's incredible!"

Impossible to see anything clearly—they keep multiplying, elusive. Then the demoness helps us, using her powers.

"Stop! Look! One bubble!"

At last, we see ONE bubble.

"You see, this one has exited eternal inflation. It's a block-universe bubble, within one of the block multiverses of the block omniverse."

And, with emotion, we recognize it—this baby bubble: "It's ours! What's gonna happen?"

We see that the quantum field of the block universe is at first a tiny point, more than microscopic—nothing could be smaller.

"Why so small?" we ask the demoness.

"Planck said so," she replies, "and there's nothing more to know."

"Planck? My friend Planck… And then?" We can't see much.

"That's normal," explains the demoness. "You see? The five knights keep colliding, fighting one another, so it forms something like a perfect gas, very simple. At least… for now… We almost burned up!" exclaims the demoness.

Heat and high density, a fierce battle among the knights that could have gone on indefinitely. But—

"Careful!" cries the demoness.

Suddenly, we're at a loss for words—

"Look! A Big Bang!"

And immediately after, just like that, a gigantic expansion, in the blink of an eye, impossible to see. Before, there was nothing, and in a micro-instant there was a universe.

"Phew!" says the demoness. "We got through that."

"But what happened?"

"That's Schrödinger's doing," the demoness smiles.

"Who's that now?"

"I know him, he's a friend of Planck!" one of us exclaims, a bit more smarter than the others.

**Figure 52** On the left, the physicist Erwin Schrödinger (1887–1961), and on the right, the physicist Max Planck (1858–1947), both of whom made fundamental contributions to quantum mechanics.

The demoness explains: "There were fluctuations, uncertainties, and they produced differences in density and temperature. At first microscopic, and then—there you go! Whoosh! The block universe!" she cries in turn.

"But how does that happen? It's so beautiful!"

"It's simple," replies the demoness, in a scholarly tone. "Schrödinger's fluctuations expanded along with the rest of the expansion of the Big-Bang-block universe, and that's how it gave rise to what we see: matter, stars, galaxies, clusters, and superclusters of galaxies—all these large-scale structures."

"How beautiful!" we exclaim, both amazed and impressed.

"The journey is over, my dears! That's where you come from—and where you will return. One planet among an infinity of billions of planets…"

And whoosh! We found ourselves back here. Yes, here—right here!

**After the demoness, a zombie!**

What contemporary philosophy calls a "zombie" has nothing to do with the folkloric undead. It is a being strictly indistinguishable from an ordinary human from a behavioral and functional point of view: it perceives, speaks, reasons, remembers, describes its mental states, and passes a Turing test[152]. Yet, by hypothesis, it experiences nothing. No lived experience, no "what it is like," no consciousness. Externally, everything is there; internally, nothing.

The problem is immediate: how could one, in practice, distinguish such a zombie from a conscious human? If there is no observable criterion that allows us to tell the difference, then either the zombie is possible but undetectable, or it is conceptually incoherent. Some accept its logical possibility in order to argue that consciousness goes far beyond any physical description; others maintain that complete functional duplication necessarily entails consciousness, and that the zombie is a poorly formed fiction.

[152] A Turing test is a thought experiment proposed by Alan Turing in 1950 to evaluate machine intelligence. If, in a blind dialogue, a human interlocutor cannot distinguish the machine from another human, it is considered to exhibit intelligence comparable to that of a human.

Let us push the difficulty to its limit by returning to a minimal ground, not idealist but phenomenal. The only indubitable fact is the evidence of my own consciousness. Of others, I have only behavioral indications. I could, in principle, take them all to be zombies. This solipsistic stance radicalizes the question without resolving it, by refocusing the problem on experience itself. Now, if we adopt the four-dimensional model of the block universe, brains, their neuronal states, their micro-level molecular fluctuations are entirely inscribed within the geometry of the block. The processes we correlate with consciousness are fixed there just like any other physical event. To say that "thought is part of the block" is to say that these neuronal configurations are determined spacetime structures.

But then the difficulty reappears, even more sharply: if everything, including the neuronal correlates of consciousness, is geometrically inscribed in the block universe, what makes there be experience rather than mere structure? What distinguishes, within the block, a conscious brain from a perfectly isomorphic zombie brain? In other words: what, within this four-dimensional geometry, constitutes the fact that it is lived? It is at precisely this point that the question can shift toward a physical reformulation. The issue is no longer to ask "where is the seat of consciousness?", but under what dynamical conditions does a structure of the block cease to be a mere configuration and become a process—necessarily irreversible—of "reading the block"? This shift in perspective naturally opens onto entropy.

### Entropy in the mind

Of course, the reader will have understood that the purpose of this imaginary excursion with the demoness was to help us grasp that consciousness is not IN the block universe. It is what moves across it, what reads it, much like a medical scanner slices your body into successive images. The demoness and the "we" accompanying her had, of course, to be exempt from this slicing and endowed with a "consciousness" that sees, feels, marvels, and so on. And yet, the question still remains: where is this consciousness? In particles, atoms, matter, the cosmos, microtubules, brain glands? Nay!

The journey with the demoness showed us a fully frozen block universe, where nothing sees anything. Even brains are motionless there, like fossils of moments. What moves across the slices is not an

organ of the block, but a reading. And every reading presupposes an asymmetry, a direction, a before and an after. Once again, the question is not: "where is consciousness located?" The question is: "under what physical conditions can a system produce this direction of reading?" Not being in the world, consciousness can only be the effect of an irreversible dynamic process. In other words, like a local form of increasing entropy.

Being conscious is an intimate act, internal to our thought—and, as zombies show, it is not visible. The most reliable way to actualize one's consciousness is therefore to moralize it: the well-known moral conscience. And for that, nothing is more effective than questioning what often underlies it: free will. Do we have it or not? That is the question. Is free will an illusion? Are we part of the fabric of the block universe, and thus entirely determined? Or do we possess that famous free will that is supposed to define human consciousness?

As Robert Sapolsky[153] explains, the idea of an autonomous free will dissolves as we extend the timescale. In the second preceding an action, our so-called "free will" depends on the neurochemical state of our brain. In the minutes before, on circulating hormones. In the hours and days before, on stress, sleep, and social context. In the years before, on learning, environment, and culture. And further upstream still, on fetal development, genetics, and evolutionary history.

Even the choice of an adjective in a statement can influence a jury's evaluation through simple priming and framing effects, Sapolsky explains. A defense lawyer who uses the neutral term "inappropriate" rather than the morally charged "bad" will influence the jury. Yet the lawyer's "choice," driven by the aim of defending the client, is no more "free" than the jurors' reaction. Nor is that of the accused, who acted under multiple social, environmental, and developmental factors, and so on. Everyone in a courtroom is the temporary point of convergence of an extraordinarily dense causal chain.

If one individual can modify another's behavior through words, arguments, and framing, it might seem that they exercise a "creative" causality, opening a real bifurcation in the course of events. In other words, their intervention appears to introduce a

[153] Sapolsky, 2025, 2026.

local indeterminacy: without them, the jury would have judged differently; with them, it judges otherwise. This gives the impression of a margin, a space of freedom.

In reality, the lawyer's intervention merely adds another link to the deterministic network. The lawyer is determined to use certain terms by training, experience, strategy, temperament, and personal history; the jury is determined to respond according to its biases, affects, and context; the accused was shaped by other constraints still. The entire system is an entanglement of reciprocal influences with no sovereign center.

From the perspective of the block universe, nothing "unfolds": these interactions are inscribed as a complete four-dimensional structure. Our brain is thus "free" in the sense that it produces internally coherent choices, but those states themselves are fully determined. Free in experience; determined in cosmic geometry.

The courtroom example shows this clearly: the question of free will is largely associated, in common imagination, with harmful acts. Moral conscience still seems to be invoked in this strange equation some make between rejecting free will and unleashing a kind of savagery or madness.

In his work on determinism[154], Sapolsky cites Gilberto Gomes[155]: "[rejection of the idea of free will] leaves us with an incomprehensible picture of the human world, since there is no responsibility or moral obligation in it. If one could not have done otherwise, it cannot be the case that one ought to have done otherwise." Sapolsky also cites Daniel Dennett, according to whom, if there were no free will: "there would be no rights, no recourse to authority to protect against fraud, theft, rape, murder. In short, no morality [...] Do you really want to return humanity to [...] Thomas Hobbes's state of nature where life is nasty, brutish and short?"[156]

For Sapolsky, "rejecting free will does not condemn you to go astray," provided one has been properly educated, in order to understand consciously where behavior really comes from. One must therefore learn what determinism is. Let us return to the courtroom, insofar as it is the scene par excellence where factors and

[154] Sapolsky, 2025, p. 397.

[155] Gomes, 1998.

[156] Caruso, Dennet, 2018.

determinisms are displayed and linked to actions. What would happen if the one who must judge were to turn the same deterministic arguments back on the accused? A thought experiment:

> The condemned man: "But Your Honor, I don't have free will. It's my genes, my childhood, everything I've lived through—I can't help it! I killed, but I couldn't do otherwise. And besides, we're in an Einsteinian block universe where everything exists in an eternal present and just unfolds. I really can't help it." And the judge replies: "Well, as it happens, this morning, while shaving in front of my mirror, I was telling myself exactly the same thing as you: I have no free will—it's my genes, my childhood, my upbringing, everything I've lived through—I can't help it! And besides, it's the law: I'm going to have to sentence you to life imprisonment for the crime you committed, but I can't help it either, truly! That's how it is, it's automatic, you see? And as you say, with Einstein, we are in a block universe where past, present, and future coexist. And this is how it unfolds: I am going to put you in prison—*ad vitam aeternam*!"

**The past hypothesis**

Laplace's demoness's excursion revealed it to us: we inhabit a four-dimensional block universe, fully laid out, where nothing changes and nothing is decided. Consciousness and free will introduce no possibility into it. What is, is already inscribed in the fabric of space-time. The entire history, from the cosmic microwave background to the final thermodynamic states, coexists there without any privilege granted to the present.

Long before Einstein, Western science was built on the hypothesis of total determinism. This is not merely an ontological thesis, but the very condition of possibility of the scientific method. The universal principle of causality, which holds that every cause produces its effect and every effect proceeds from a cause, grounds prediction, explanation, and technical efficiency. Without this strict continuity of chains of events, neither laws, nor calculation, nor mastery of the world would be conceivable.

We live in a deterministic universe, not only because the natural principle of cause and effect reigns within it, but because its very structure is four-dimensional. In such a framework, there is no instance that would intervene to bend the course of things: there is only the complete unfolding of space-time. Events do not happen; they are.

No one acts in the strong sense. Nothing tears itself from the fabric of the world in order to alter its weave. Everything is already inscribed in the geometry of the block, like the images of a film whose every frame exists stacked on the reel. The unfolding is only an internal perspective, a local reading of what, in reality, is given all at once.

Where does this determinism come from? From where do these causes arise that chain effects together? The answer lies not only in a metaphysics of necessity, but in the statistical dynamics of the physical world. Since the nineteenth century, Clausius, Boltzmann, Maxwell, and Gibbs placed irreversibility at the heart of thermodynamic systems; in the twentieth century, Shannon and von Neumann extended the notion of entropy to information, Eddington made it the arrow of time, Prigogine explored dissipative structures, and Penrose linked the extremely low initial entropy to gravitational geometry. The universe, having begun from an extraordinarily ordered state, evolves toward statistically more and more numerous configurations. The local determinism of laws is thus inscribed within a global drift toward maximal disorder.

From this perspective, Sean Carroll[157] proposes that consciousness and the feeling of free will should be understood as emergent phenomena of a universe with increasing entropy. Memory, anticipation, and deliberation would not be escapes from the block, but informational structures made possible by temporal asymmetry itself. The feeling of being able to act would then arise from our inscription within this arrow, not from a break in the chain of causes.

We will place ourselves resolutely within an entropic analysis of consciousness, at a distance from what will later be called the myth of consciousness. A mythical vision, then, which includes both

[157] Carroll, 2022b, p. 65.

"spiritualists" [158] in the manner of Descartes, who place consciousness and matter side by side in a separate way, and those who raise consciousness to the status of a fundamental property of matter, in the name of a basic psychophysics, as in Chalmers. We find again, in the same vein, consciousness as a fundamental and omnipresent property of the physical world in Goff; consciousness anchored to an ultimate structure of quantum gravity in Penrose; consciousness derived from the informational texture of the cosmos in Wheeler; finally, consciousness conceived as an internal property of certain mathematical structures in Tegmark.

These psychophysical hypotheses have in common that they elevate consciousness to the rank of a primary ontological element. The entropic approach, by contrast, grants it no fundamental privilege: it situates consciousness within the irreversible dynamics of a universe with increasing entropy, as a local, transitory, and structured configuration of information inscribed in the very geometry of the block.

For fundamental physics, there is no intrinsic asymmetry between past and future. The dynamical equations (whether in classical mechanics, electrodynamics, or quantum mechanics in its superposed form) are reversible: they allow evolution both toward what we call the future and toward what we call the past. In such a framework, the figure of Laplace's demon arises naturally: knowing the exact state of all the components of the universe and the laws that govern them, it could deduce in full both what we call the past and what we call the future. Determinism is thus trans-temporal, inscribed in the totality of the block.

What remains is the asymmetry of our lived experience. Our experience is oriented: we have traces, memories, archives, which fix with relative certainty what has been, whereas the future presents itself only through probability distributions, anticipations, projects, and the irreducible possibility of surprise. This asymmetry does not come from the fundamental laws, but from our local embedding in a universe with increasing entropy. Memory is a physical structure correlated with past states; it requires an increase in entropy and produces stable traces. There are no traces of the future, not because it would not yet really exist, but because entropic dynamics does not

[158] For reference: Bergson, Nagel, McGinn, Strawson, Marion…

allow reverse recording. Thus, the orientation of consciousness does not contradict the determinism of the block: it is one of its internal statistical effects.

For Carroll: "The way to reconcile these ideas (the past is fixed once and for all, while the future can still be changed, yet the laws of physics are reversible) ultimately comes down to entropy."[159] Laplace's demon may well know everything within the temporal fabric of the block universe, and his twin demoness may move through it at will; for us, human consciousnesses, this is not the case.

Carroll formulates what he calls the "Past Hypothesis": the universe would have begun in a state of extremely low entropy, a necessary condition for the arrow of time to emerge at the macroscopic level. The difference between the demon, the demoness, and us clarifies this point. The demon, informed by microphysics, would have full access to the elementary degrees of freedom; the demoness, situated outside the block, would grasp its entire geometry and could examine its slices. We are neither. We are macroscopic systems, internal to the block, immersed in coarse-grained variables, unable to access microscopic detail[160] and, above all, unable to step outside the four-dimensional structure to contemplate it.

Within this framework, the low entropy of the past, that is, its high degree of order, makes possible the stable correlations that are traces, archives, and memories. Memory is a physical recording of prior configurations, made viable by this particular initial condition. The future, by contrast, corresponds statistically to states of higher entropy, hence to an increased dispersion of exploitable correlations. It cannot leave traces in the present and appears only through probability distributions. The orientation of our experience does not signal an ontological openness of time, but our internal position in a universe that began in extreme order and evolves toward maximal disorder, as developed by Sean Carroll.

The positive side of this experienced indeterminacy of the future is one of the cores of our conscious experience: free will. What we are going to do appears to us as uncertain as the configurations of the

[159] Carroll, 2022b, p. 65.

[160] One need only become aware of the difficulties and paradoxes we are confronted with in quantum mechanics.

world we are going to encounter. This subjective symmetry between external future and internal future feeds the impression of openness: several outcomes seem equally possible, several decisions equally accessible.

But this openness is phenomenal, not ontological. It stems from our ignorance of microscopic details and from our macroscopic embedding in an entropic dynamic in which the future leaves no trace. We then interpret the absence of information as a space of choice. Within the limits imposed by physical, biological, and social constraints, this epistemic indeterminacy is lived as freedom. It introduces no breach in the block; it is the way a finite cognitive system, immersed in a determined universe, represents its own becoming.

Because we are in a universe characterized by an arrow of time, nothing can be changed about the past, whereas for the future, our impression of free will opens onto certain possibilities. This is an effect of the entropic gradient, low → high, order to disorder, in the universe that is ours. From this point on, we will posit three postulates defining consciousness within the strict framework of the block universe:

(1) Consciousness, or thought, is a product of the human brain, that is, of the organization and activity of its neurons. It is not a distinct substance nor a fundamental property of matter, but an emergent biological phenomenon inscribed in neurophysiological dynamics.

(2) As such, consciousness is a behavior, an action of the nervous system. To think, to remember, to decide, to imagine are not states suspended outside the physical world, but processes, hence events localized in space-time, subject to the general laws that govern any other natural phenomenon.

(3) The set of functionally active elements of the brain (cortical areas, neural nuclei, individual neurons, molecules, atoms, particles involved in brain activity) forms worldlines within the four-dimensional block. Consciousness is nothing other than a certain correlated configuration of these worldlines, seen from within by the system that constitutes them.

On the basis of these three postulates, we will rely on the analyses of Sean Carroll, which articulate entropy and consciousness without departing from the physicalist framework. We consider a universe arising from a Big Bang, preceded by a phase of primordial inflation and continuing its expansion under the regime of dark energy. In its phenomenal description, the universe begins in a state of extremely low entropy and sees this entropy increase over time. In the Einstein–Friedmann version of the block universe, this low entropy lies at the extremity we call the origin, then increases along the four-dimensional tube.

It is this entropic gradient, internal to the geometry of the block, that makes possible the complex informational structures that are brains, and thus consciousness. It generates the impression of "reading" or "scanning" the block, the impression of a flow of time, the impression of an open future and of free will. These phenomena are not fundamental properties of reality, but macroscopic effects linked to our local position in an entropically oriented structure. The whole constitutes what can be called the myth of consciousness: not a trivial error, but a phenomenal construction necessary for a finite cognitive system embedded in a determined universe.

**The Myth of Consciousness**

If the illusion of conscious flow is stable, coherent, and nearly universal among humans, it is not because it reveals something true about time, but because it is the only viable form of local consciousness in a block universe, for at least five reasons.

First, the **local entropic constraint**. Human brains are dissipative systems. They can function only by exporting entropy. This imposes an irreversible asymmetry in their internal functioning. Even if the global universe is symmetric or static, any region capable of complex cognition is necessarily oriented along an entropic gradient. This orientation automatically produces a past/future distinction, independently of any real ontology of time. In other words, a consciousness without a local entropic arrow would be unstable, or simply impossible.

Second, the **architecture of memory**. The human brain is massively retrospective. It stores traces, not global states. Each conscious state contains: – neural inscriptions interpreted as

memories; – predictive models interpreted as the future. This asymmetry is neither cultural nor learned. It is structural. A brain that would symmetrically store "past" and "future" would be unusable, because it could neither act nor learn. The coherence of the flow is therefore a direct consequence of informational compression: the brain reconstructs a minimal temporal narrative compatible with its internal traces.

Third, **evolutionary selection**. Any consciousness capable of survival must: – attribute causes to what is already encoded; – project consequences toward what is not yet encoded; – represent itself as persistent. A consciousness that experienced itself as a series of disjoint snapshots, or as a timeless structure, would be unfit for coordinated action. The continuity of the self is not a metaphysical truth, but a condition of behavioral stability. This point is crucial: the human universality of the illusion comes from the fact that any viable human consciousness must share this minimal architecture.

Fourth, **intersubjective locking**. Humans live in synchronized social networks. Language, shared causality, and collective memory impose a narrative compatibility between individual consciousnesses. A human consciousness that did not reconstruct a temporal flow aligned with that of others would be immediately marginalized or pathologized. The illusion is therefore socially reinforced, not by arbitrary convention, but by the necessity of coordination.

Finally, and decisively, the fifth reason is the **impossibility of an external point of view**. There exists no internal mechanism allowing a region of the block to represent itself as a region of the block. Every consciousness is confined within a local slice. It can represent only correlations, never the whole. We are neither demon nor demoness. The flow is the minimal form taken by this structural ignorance.

In summary, the illusion of lived time is: – stable, because it is constrained by entropy and neurophysiology; – coherent, because it is produced by informational mechanisms of compression and prediction; – universal among humans, because no other form of human consciousness would be viable, either biologically or socially. Our consciousness is like the falling cup: it does not "choose" to shatter upon hitting the ground, it simply follows the irreversible slope of entropy, which transforms an ordered configuration into a

dispersion of possibilities, only one of which is actually realized; and the cup will not rise back up and reassemble itself on the table, not because the laws of physics would forbid it, but because entropic dynamics makes such an outcome statistically impossible. In a block universe, it is not surprising that all human consciousnesses are deluded in the same way. It would, on the contrary, be surprising if they could fail to be deluded. Unless…

**Block universe and meditation**

A section that may seem unusual in a work that has so far aimed to be scientific, but the reader can be reassured. The appeal to meditation does not here amount to a return to irrationality. The works of Chögyam Trungpa, a Tibetan lama trained in the Buddhist tradition yet attentive to the intellectual demands of the modern world, already testify to this in their very titles: *The Myth of Freedom and the Way of Meditation* [161] , *Cutting Through Spiritual Materialism*[162]. Far from encouraging a mystical escape, Trungpa instead seeks to bring to light the illusions of spirituality itself—those that surround the practice of meditation, as well as those that shape our ordinary conception of consciousness. In this perspective, meditation does not aim to produce a new belief about the mind, but to reveal, behind mental agitation and conceptual constructions, a form of ineffable substrate of experience. It is this point that we will attempt to relate to a "demon-like" view of the block universe. Such an approach will lead us to move beyond both the myth of a consciousness separate from matter and that of a consciousness dissolved into the particles of the world.

The learning of meditative practice will not be addressed in this work[163]. This more philosophical section is primarily intended for experienced readers. However, anyone, regardless of their level of meditative practice, may benefit from understanding the spirit and aims of meditation.

[161] Trungpa, 1976.

[162] Trungpa, 1973.

[163] For this, see *Meditation in Action*, by Chögyam Trungpa, 1969.

**Figure 53** Artist's illustration of Siddhārtha Gautama in meditation.

The Buddhist concept we will attempt to align with that of the block universe is that of *Śūnyatā*[164], vacuity[165]. Its canonical definition is found in the Prajñāpāramitā (Perfect Transcendent Wisdom)[166]. In the section entitled the "Heart *Sūtra*," one of the shortest and most famous texts of the Prajñāpāramitā corpus. In this text, Avalokiteśvara[167] responds to a question from Śāriputra[168]. Both are in the presence of the Buddha, who is meditating[169].

Śāriputra asks Avalokiteśvara how to understand Prajñāpāramitā. Avalokiteśvara replies by positing the equation between all phenomena and vacuity. The five "aggregates" that constitute the individual in Buddhist doctrine are: form, that is, the body and materiality; sensation or feeling, pleasant, unpleasant, or neutral impressions; perception or recognition, which identifies and names objects; mental formations or acts of will, the set of dispositions, impulses, and psychic constructions; consciousness, the cognitive consciousness linked to the senses and the mind. These five aggregates are vacuity, which means that none of them possesses any independent or intrinsic existence.

In the doctrine of vacuity, to say that the five aggregates have no independent existence means that they possess no intrinsic nature. No aggregate exists by itself, in an autonomous, stable, and independent way. Each appears only in dependence on other causes and conditions. For example, form depends on physical and biological processes; sensations depend on the contact between sense organs, objects, and consciousness; perception depends on cognitive structures; mental formations depend on habits, conditioning, and

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[164] Pronounced "shoon-yata".

[165] We have avoided the interchangeable term "emptiness," although it is used in Buddhist literature, as it is already widely used and carries specific connotations in physics and cosmology; we therefore prefer the term "vacuity" to preserve a clear conceptual distinction.

[166] Dawa-Samdup, 1958. The reader wishing to explore this text further may also refer to Nāgārjuna, 1993 and Avalokiteśvara, 2001.

[167] Avalokiteśvara, a major bodhisattva (a practitioner engaged on the path to Awakening) in Mahāyāna Buddhism.

[168] Śāriputra, one of the principal disciples of the historical Buddha.

[169] The text can be found at the end of the work by Dawa-Samdup, 1958, pp. 355-58.

prior causes; consciousness itself depends on the interaction between a sensory faculty and its object. Nothing exists in isolation.

Vacuity therefore does not mean that the aggregates do not exist at all, but that they do not exist "in themselves." They exist only in a relational, conditioned, and impermanent manner. This is what Buddhis [170] expresses through "dependent origination": every phenomenon arises in dependence on other phenomena. From this point of view, the individual is not a substantial entity, but a dynamic aggregate of physical and mental processes. What we call the "self" is only a conventional designation applied to this changing ensemble. Prajñāpāramitā pushes this reasoning to its limit: not only is the self vacuity, but the aggregates themselves, which seem to constitute the ultimate reality of the individual, are also devoid of intrinsic nature.

After an even more detailed exposition of what vacuity is, Avalokiteśvara concludes his teaching by assimilating it, too, to vacuity: "There is no Path, there is no Wisdom, nothing to attain or not attain." This formulation belongs to the paradoxical register characteristic of the doctrine of vacuity. When Avalokiteśvara asserts that "there is no Path, no Wisdom, nothing to attain," he is not denying the practical existence of the Buddhist path; he is

[170] Buddhism does not constitute a homogeneous doctrinal system. Over the course of its history, it has diversified into numerous schools and traditions, often laden with beliefs and doctrinal elaborations foreign to the original teaching of the Buddha: forms of theism, doctrines of reincarnation conceived as the transmigration of a personal entity, speculations about a universal mind, primitive cosmologies, or devotional cults. In the present work, reference to Buddhism is limited to the Mahāyāna ("Great Vehicle"), and more specifically to the philosophical tradition of Mādhyamaka ("Middle Way"), associated with Nāgārjuna (second–third century). This tradition extends and systematizes the teaching attributed to the historical Buddha Śākyamuni, who never presented himself as a divine entity, but as a human being who attained Awakening, whose central doctrine brings to light the vacuity (*śūnyatā*) of all phenomena, and who affirmed the equation between *nirvāṇa* (the disappearance of the belief in the intrinsic existence of phenomena, and the psychological detachment that follows from it) and *saṃsāra* (living in a world of phenomena that appear, change, and disappear, while being caught in psychological mechanisms of attachment, desire, aversion, and illusion), vacuity applying equally to both.

denying that it possesses an intrinsic, self-existing reality. In ordinary teaching, there is a path: practices, disciplines, meditation, wisdom, progression toward awakening. But from the point of view of perfect wisdom, all of this still belongs to the domain of conceptual constructions. If all phenomena are empty of intrinsic nature, then spiritual categories themselves are as well: path, wisdom, awakening, realization.

In other words, there is no entity called "wisdom" that one could possess, nor any object or place called "awakening" that one could reach. Nor is there a real "self" that would walk along a "path" toward a "goal." The language of spiritual progression operates at the conventional level, as a pedagogical tool. But when vacuity is understood, one sees that these distinctions dissolve: there is neither subject who attains, nor object attained.

Paradox serves precisely to break attachment to the very idea of spiritual attainment[171]. In the logic of Prajñāpāramitā, believing that there is something to attain is still a form of mental grasping. Perfect wisdom consists in recognizing that nothing has ever had intrinsic existence, and therefore that there has never ultimately been anything to acquire. This is why the text can say simultaneously that there is a path and, at the ultimate level, that there is none.

Here we can see that vacuity is not a nihilism. It does not mean that nothing exists, but that nothing exists by itself, independently and permanently. Phenomena appear, transform, and disappear within a network of relations and conditions, without any stable substrate to cling to. Understanding this does not lead to metaphysical despair, but to a kind of clearing of the mind. In meditative experience, when there is nothing left to seek or attain, when the activity of grasping and mental construction subsides, vacuity ceases to be a concept and becomes a direct experience. The experience of a mind that does nothing and appropriates nothing: "doing nothing to obtain nothing."[172] It is in this suspension that there may appear, at least intuitively, something resembling the "demonic"[173] perspective on the block universe: a vision in which

[171] What Trungpa denounces as spiritual materialism.

[172] Loonis, 2023, p. 207.

[173] With reference, of course, to Laplace's demon—or his twin sister—so nothing demonic about it: no horns, no hooves.

events are no longer experienced as a flow to be conquered or directed, but as a totality already there, whose structure the mind may fleetingly glimpse without projecting itself into it as center or as agent.

In Prajñāpāramitā, the statement that "form is emptiness and emptiness is form" is central. We are faced with a kind of experiential contradiction: that of a phenomenal experience, what is called form (that which precedes all conceptualization, such as this scene, for example, where you are sitting on a bench in a public garden, with an environment, various sensations, the sight of children playing, people passing by, and this "you" on the bench, more or less comfortable, etc.), whereas since Albert Einstein we know perfectly well that we are in a block universe. The question then arises of the illusory character of lived "form," which cannot exist in itself; it is indeed a matter of vacuity.

Form precedes all conceptualization. It is important to state this clearly, because conceptualization adds to the illusion, feeds the illusion. Chögyam Trungpa, in his "spiritual materialism," shows and denounces the fact that even spirituality, even meditation, can be appropriated by the intellect. For example, in the course of a deep and advanced meditation, it may happen that one literally experiences vacuity, but that our intellectual self suddenly seizes upon it by conceptualizing it: "That's it! I am a Buddha!"

As Trungpa explains: "Form is empty if we see it in the absence of our own personal interpretations about it." And he adds: "But emptiness is also form."[174] How are we to understand this apparent contradiction? Trungpa proposes contemplating two things: a maple leaf falling and a heap of garbage. The "form is emptiness" version of this scene is that it is vacuity in the sense that the conceptualization of the leaf as "beautiful" and the garbage as "ugly" disappears. Leaf and garbage are simply there, just as they are. "Everything is fine," you might say! "Everything is perfect," and it is "very beautiful to see"—and snap! This emptiness, you have just clothed it in the form of "good, perfect, beautiful" by conceptualizing it. This is why it is said that "emptiness is also form." Vacuity is also the maple leaf and the heap of garbage.

[174] Trungpa, 1973, pp. 182-3.

In a certain sense, "vacuity" itself is already too much in experience. The key to meditation then consists in remaining in the trembling position of a drop of dew, suspended at the tip of a blade of grass and on the verge of falling. A vibration between form and vacuity, without clinging to either. Things may be beautiful or ugly, they are just as they are—that is vacuity—but at the same time we see them simply as they are, without adding anything, without conceptualization, a return to form. As Trungpa says, it is a matter of being "suspended nowhere."[175]

As Guy Bugault explains in his commentary on Nāgārjuna: "Thus, the world, the self, are neither real nor unreal; they belong to the order of illusion. Everything happens as if. This is what happens to us in the cinema: we understand the story, we believe in it. […] The world is a language, a system of signs and information, nothing more, without any referent external to the signifiers."[176]

After this somewhat spiritualizing parenthesis, devoted to vacuity in the Buddhist tradition, in Nāgārjuna or Chögyam Trungpa, the reader will no doubt have understood where we were heading. There is a dizzying gap between our ordinary experience (picturesque, animated, saturated with sensations, emotions, decisions, and personal initiatives) and, on the other hand, the scientific knowledge derived from relativistic physics and contemporary physicalism. Science describes a four-dimensional block universe, arising from the Big Bang and primordial inflation, in which time is only one dimension among others. The universe appears there as a whole already laid out—past, present, future—traversed by an entropic gradient running from a highly ordered initial state toward increasingly disordered states, this gradient producing, for organisms such as ourselves, the kinematic illusion of a flow of time and of freedom of action.

We do not know whether meditative practice can truly lead each individual to an intuition of such a block universe, but the suspension of mental constructions that meditation proposes (that moment when there is nothing left to grasp or to accomplish) perhaps offers a singular way to approach, through the mind,

[175] Trungpa, 1973, p. 184.

[176] Nāgārjuna, 2002, pp. 222-23, Our translation of the quotation.

something that resembles this strange “demon-like” perspective on the cosmos.

# 3. A universe of illusions

In a block universe, there is nothing that "appears" in the dynamic sense. There is no emergence over time, no progressive production. Everything that exists already exists as a structure of space-time. Consciousness, in this framework, is not a process that begins, unfolds, and ends. It is a local property of certain regions of the block, exactly like an energy density, a geometric curvature, or a field. It does not flow: it is distributed along the worldlines of the block.

A conscious state corresponds to a complete physical configuration of the brain at a given point in space-time. This configuration necessarily includes neural correlations, memory traces, internal models of the world, and a representation of a past and a future. These elements are not oriented toward a real time; they are oriented toward other regions of the block. The "past" is not what no longer exists, but what is correlated in a certain way. The "future" is not what does not yet exist, but what is not correlated in a determined way from that region of the block.

The key point here is this: consciousness is not what traverses the block; it is that by which the block is locally given as traversed. There is therefore no subject moving from one instant to the next. There is a sequence of regions of the block, each containing a conscious structure that represents itself as coming from the previous one. Continuity is internal to the representation, not to the ontology.

This leads to a radical but coherent consequence: the "self" is not a persisting entity. It is a relation of resemblance and coherence between neighboring conscious states in the block. To say "I remember" means: this brain configuration encodes traces compatible with other configurations located elsewhere in the block. To say "I decide" means: this configuration encodes several coherent possible continuations, without access to the one that is actually realized in the global structure. Free will, in this framework, is neither true nor false in the classical sense. It is an internal property of certain states of the block: the capacity to represent alternatives without knowing which one is globally inscribed.

One can therefore formulate the thesis in geometric terms: consciousness is a local self-referential section of the block universe, capable of encoding a history without any history actually unfolding. At this stage, the question is no longer "how does consciousness emerge from time?" but "why do certain regions of the block have this property of narrative self-representation, while others do not?"

The "flow" of consciousness is therefore not a real flow. It is a reconstruction. A local, sequential reading of a structure that is already entirely given. Exactly as if, in a book already written from the first to the last page, each page contained the illusion that it comes after the previous one and before the next.

Sean Carroll, who explains the arrow of time by increasing entropy in our Big Bang–type universe, attributes to this arrow of time the power to generate the illusion of flow: "The arrow of time explains why time seems to flow around us, or (if one prefers) our impression of evolving through time. It is the reason why we remember the past but not the future, the reason why we evolve, metabolize, and ultimately die. The reason why we believe in notions of cause and effect—and this is essential for our conception of free will. And all of this because of the Big Bang."[177]

The idea that the world as we experience it is not the ultimate reality appears in several philosophical and religious traditions.

In Buddhism, particularly in the Mādhyamaka tradition, the phenomenal world is often compared to a dream, a magical illusion, or a mirage. This comparison does not mean that phenomena do not exist, but that they do not exist in the way we believe they do. We spontaneously attribute to them an intrinsic, stable, and independent existence, whereas in reality they appear in a conditioned and interdependent manner. This error of grasping gives rise to attachment, aversion, and the illusion of a separate self. The doctrine of vacuity (*Śūnyatā*), systematized by Nāgārjuna, asserts that all phenomena are devoid of intrinsic existence. Thus, the world as perceived by ordinary consciousness resembles a dream: it has a conventional reality in experience, but it does not correspond to an ultimate reality possessing its own essence.

[177] Carroll, 2022b, p. 13.

In Hinduism, particularly in Advaita Vedānta, the concept of *māyā* designates precisely the appearance of the phenomenal world. The perceived world is real at the level of ordinary experience, but it is considered a manifestation or appearance that veils ultimate reality, *Brahman*. Illusion does not mean that nothing exists, but that the way things appear to consciousness does not correspond to their deeper nature.

In Greek philosophy, a similar idea is found in Plato with the allegory of the cave. Prisoners take the shadows projected on the wall to be reality itself, whereas they are only appearances produced by objects located elsewhere. Ordinary perception is thus understood as a form of illusion in relation to a more fundamental reality accessible through knowledge.

In certain forms of Christian or Neoplatonic mysticism, the sensible world is likewise presented as an appearance or an image of a deeper reality. The emphasis is often placed on the fact that visible things are only transient manifestations of a more fundamental order.

In modern philosophy, this intuition reappears in different forms. Arthur Schopenhauer, for example, speaks of the world as representation: what we perceive is a construction of our cognitive apparatus. Immanuel Kant also distinguishes between the phenomenon—the world as it appears to our sensibility and understanding—and the noumenon, the thing in itself that remains inaccessible.

Even some contemporary interpretations of physics and cognitive science move in this direction, emphasizing that perception and consciousness construct models of the world rather than providing direct access to it. The idea that ordinary experience resembles a kind of "waking dream" is therefore not unique to Buddhism, even if it has made it one of the central axes of its analysis of mind and reality.

If we consider consciousness as the general framework, the fundamental illusion is that of a subjective center, the Self[178], from which we can consider the whole set of illusions structured around this supposed center, passing through the psychological construction of the world and culminating in the physical world as it is interpreted by consciousness. An extended list of the illusions of

[178] Often also referred to as the "ego."

consciousness can be organized as follows: the self; the agent; free will; sensations and perceptions; mental representations; conceptions; coherence; destiny; spatiality; temporality; motion; energy; fundamental interactions; the laws of Nature; causality.[179] We will examine them one by one.

**The illusion of the self**

An "aggregate of tendencies," as Buddhism so aptly defines it, the self is no doubt the first of all illusions. Usually, each person experiences himself as a stable subjective center located "here," at the heart of body and mind, from which the world is supposedly perceived and actions decided and carried out. The feeling of a "self" appears to be a local effect of the brain's functioning: an internal model that unifies perceptions, memories, and intentions in order to organize behavior. The "self" is therefore not a real center in the universe, but a construction generated by cerebral processes, a cognitive fiction useful for organizing experience, yet devoid of any existence of its own.

**The illusion of the agent**

The self is experienced as an agent: an entity capable of acting, pursuing goals, making decisions, and producing effects in the world. This impression of agency gives the feeling that there exists, at the center of the individual, an instance that initiates actions and

[179] We have selected fifteen of them, among the most important, but the illusions of consciousness are innumerable. One could also mention, for example, the illusions of irreversibility, evolution, assigned meaning, identity, separation, stability, importance, purpose… But we would be unforgivable if we did not say a few words about, without a doubt, the greatest of illusions. It carries us through youth and is revealed to us decades later, when it begins to loosen its grip. Then we discover, dismayed, that it has deceived us from the end of childhood all the way to gray-haired age, through a neurobiological program designed to ensure the reproduction of the human species! With its feelings, its emotions, its joys and its depressions, its poems and its novels, its "interchangeable unique objects" (Freud), its superhuman devotion, its crimes of passion, its addictions with their irresistible desires, their dependencies, their lacks and their long-term relapses… and it never ends, all of it driven by the illusory effect of a… neurobiological program: love!

directs the course of events. The brain constructs an internal model in which certain causal chains are interpreted as "my actions" oriented toward goals. Thus, the agent is not a real entity acting in the world, but a construction of the brain that attributes the origin of actions to an imaginary center.

**The illusion of free will**

Throughout life, each person experiences himself as capable of freely choosing between several possibilities and thus directing the course of events. This impression is reinforced by the subjective experience of deliberation: options are weighed, one hesitates, and then a decision seems to arise as the expression of a personal will. The feeling that one could have acted otherwise comes from the fact that the brain mentally simulates several possible scenarios before an action actually occurs. This simulation creates the impression of a genuine openness of possibilities, whereas it is only an internal process of calculation and anticipation. Some naïve models even go so far as to implicitly imagine a little decision-maker lodged somewhere in the brain, a *homunculus* tasked with choosing between options. But such an entity would merely shift the problem, since one would then have to explain how this *homunculus* itself decides: is it a cluster of neurons? Is it a single neuron? And if so, where does this neuron get the fact that it produces a nerve impulse? And so on, in an infinite regress toward the quanta, without ever reaching what would truly decide. Free will is thus a subjective interpretation of cerebral, psychophysical processes which, for their part, do not escape the determination of the world.

**The illusion of sensations and perceptions**

From sensations, sensory experience gives the impression that we directly perceive an external world endowed with its own qualities: shapes, colors, sounds, textures, smells. Yet what we call perception begins with simple physical stimulations captured by the sensory organs. These signals are then transmitted and transformed by the nervous system, and subsequently integrated in different regions of the brain, which construct a coherent representation of the environment. In this process, the brain establishes a functional distinction between an "inside," the body and its states

(coenesthesia), and an "outside," what surrounds it. The qualities we attribute to perceived things are therefore not present as such in the world, but result from this internal construction[180]. This perceptual elaboration is closely linked to the fundamental emotional tendencies of living organisms: attraction toward what appears favorable, repulsion from what seems threatening, and indifference toward what has no immediate stake. The perceived world is thus a functional interpretation produced by these sensory-perceptual systems, and not a reality that would exist independently of this perceptual activity.

**The illusion of mental representations**

Beyond immediate perceptions, the brain constantly produces internal representations: mental images, memories, anticipations, fantasies, beliefs, theories, or models of the world. These contents give the impression that an inner space exists in which ideas are formed and circulate, as if the mind were manipulating mental objects distinct from physical reality. In reality, these representations are reducible to particular configurations of brain activity. They result from the brain's capacity to record traces of the past, to recombine these traces, and to simulate possible situations in order to guide behavior. Mental representations thus give the impression of an autonomous inner world, whereas they are nothing more than physical processes that model, in a partial and pragmatic way, certain aspects of the world.

**The illusion of conceptions**

Within mental representations, the human mind develops conceptions: intellectual constructions that organize and interpret experience. The brain categorizes, distinguishes, names, classifies,

[180] If we take the example of vision, the light photons that reach us from the world stop at the retina, which detects them. Beyond that point, there is no more light. What remains are electrochemical signals that travel along the optic nerves and reach the visual areas at the back of the brain. There, these signals are processed according to different parameters (for example, the orientation of lines, contrasts, the interpretation in "colors," etc.), ultimately giving rise to the conscious experience of seeing, constructed by the brain.

and applies labels to things, beings, and situations. From these operations emerge worldviews, systems of interpretation, beliefs, and logical frameworks within which phenomena are understood. The mind can then manipulate these constructions, combine them, extend them, challenge them, or even build interpretations of interpretations. Around this conceptual work, the self constructs a personal paradigm made up of patterns of thought, mental attitudes, values, and mindsets that give the individual an impression of coherence and stability. Conceptions thus create the impression that the world possesses natural divisions and intrinsic meanings, whereas they are only interpretative schemas elaborated by the human mind.[181]

**The illusion of coherence**

The human mind spontaneously tends to organize what it perceives and thinks according to patterns of coherence. Events are linked together, phenomena are interpreted as part of an intelligible order, and the world as a whole appears structured according to a certain rationality. This tendency leads us to give meaning to things, to situations, and to the world; to seek explanations; to construct narratives that connect facts to one another; and to perceive the universe as a system that is, on the whole, understandable. The coherence we perceive in the world gives the impression that the universe possesses an intelligible order of its own, whereas it corresponds, above all, to the way the brain structures experience in order to make it usable.

**The illusion of destiny**

We tend to interpret our own existence as an oriented trajectory, a path that would have a particular meaning and would lead toward some form of fulfillment or fatality. Life events are then reorganized into a narrative: certain encounters become decisive, certain trials appear necessary, strokes of luck seem providential, and the whole

[181] The attentive reader will note that this present work, filled with conceptions, is nothing more than an illusory emanation of its author's brain. It is for the same reason that the Prajñāpāramitā cancels itself out by declaring that "There is no Path, there is no Wisdom, nothing to attain and nothing not to attain." In this sense, there is no "Omnivers."

ends up giving the impression that a personal path is taking shape. This tendency also extends to the lives of others, and sometimes to collective history, as if each existence followed a destiny already inscribed somewhere. A large part of this impression comes from the retrospective reinterpretation of events: after the fact, episodes of the past are reinterpreted so as to form a continuity and to fit with the idea of a trajectory that would have been, in some sense, planned or "written." The feeling of destiny arises from the brain's narrative work, which links memories, selects certain events, and assigns them an overall meaning. Destiny thus appears as a retrospective interpretation of life rather than a real property of the world.

**The illusion of spatiality**

Our immediate impression is that we live in a three-dimensional space clearly structured by length, width, and height, within which objects are arranged at different distances in depth and occupy defined positions. This spatiality seems obvious: we locate things in front of or behind us, near or far, to the right or to the left, above or below. Yet what we call three-dimensional space is, first and foremost, a perceptual construction elaborated by the brain from multiple sensory cues: stereoscopic vision, bodily movement, variations in perspective, parallaxes, and tactile and vestibular information. The brain combines these signals in order to produce a coherent spatial model within which the organism can orient itself and act. Spatiality is a functional model, produced by the brain, to make the environment manipulable and intelligible at the human scale.

**The illusion of temporality**

"O time, suspend your flight! and you, propitious hours, suspend your course!"[182] Ordinary experience gives the impression that time flows, to the point that, at times, some opportunists would like to stop it. A past recedes behind us, a present unfolds now, and a future opens before us. Clocks measure this passage, while the body itself seems to possess internal rhythms that mark durations. Memory preserves traces of the past, recollections organize personal and collective history, and anticipation projects the mind toward what

[182] Alphonse de Lamartine, *The Lake* (1820).

might occur[183]. The whole creates the illusory sensation of a continuous succession of moments unfolding one after another.

**The illusion of movement**

We have the impression that everything is in motion. We get up, walk, sit down, type on a computer keyboard. Around us, things also seem to move: a bird crosses the sky, an airliner speeds high above, a cat crouched in the grass suddenly leaps toward a butterfly that escapes as it takes flight, foliage sways in the wind, waves roll onto the shore, cars travel along the road, and even the sun appears to move across the sky over the course of the day. The world thus presents itself as a set of objects that change position in space over time. The impression of movement arises from the functioning of the brain, which compares successive perceptual states and interprets them as the continuous transformation of a single object.

**The illusion of energy**

In the scientific description of the world, energy appears as a fundamental quantity: it allows us to describe work, physical transformations, exchanges between systems, and dynamic equilibria. It seems to flow, to transform from one form into another (mechanical, thermal, chemical, electromagnetic). It can be conserved or degraded. In everyday life, just as in scientific language, we thus speak of an energy that is transferred, stored, dissipated, or degraded. An abstract concept, energy essentially serves to express relationships between physical states and to formulate general principles. Gradually constructed as a theoretical concept, energy is entirely a product of the human brain.

[183] Research in neuroscience has shown that the brain regions involved in memory of the past are largely the same as those mobilized when we imagine the future. The hippocampus and several regions of the associative cortex participate both in the construction of memories and in the simulation of future events. The brain therefore does not truly "see" the future: it recombines fragments of past experience to construct possible scenarios. In other words, the imagined future appears, to a large extent, as a "futurized" past (Schacter, Addis, Buckner, 2007).

**The illusion of fundamental interactions**

Physics describes the universe using a small number of fundamental interactions: electromagnetism, the strong interaction, the weak interaction, and gravitation. In everyday language, these interactions are often presented as forces acting at a distance or as fields that fill space and exert their influence on particles and bodies. This way of speaking gives the impression that there exist, in nature, dynamic entities that push, attract, or hold things together. Quantum mechanics, however, gives these entities an elusive character. At the scale where these interactions are supposed to operate, the entities that carry them can no longer be described as well-defined objects. The work of Erwin Schrödinger and Werner Heisenberg showed that particles and fields possess neither definite position nor trajectory in the classical sense: they are described by a wave function, probabilities, and mathematical operators. Quantum indeterminacy prevents us from attributing precise properties to the ultimate constituents of matter independently of detection and measurement. Under these conditions, "forces" or "fields" appear less as tangible realities than as conceptual structures that allow us to organize and calculate the observed regularities. Fundamental interactions thus become extremely effective intellectual tools: they do not exist as entities that could be directly grasped, but as purely mathematical models, products of the intellectual work of the human brain, which describe with great precision the correlations between phenomena.

**The illusion of the laws of Nature**

Science describes the universe using laws: laws of motion, laws of gravitation, equations of electromagnetism, principles of thermodynamics. These laws give the impression that there exist, in Nature, deep rules that govern phenomena and direct their evolution. The world thus seems to obey a kind of universal code that determines what can or cannot occur. Yet these laws are descriptions that we formulate, through our intellectual work, to account for the regularities observed in the world. What we call the laws of Nature therefore corresponds to mathematical models that summarize these regularities and make it possible to predict certain relationships between different states of the world. However, the laws of Nature themselves remain conceptual formulations

produced by the human mind to describe the order we recognize in the structure of the universe.

### The illusion of causality

In ordinary experience, as in scientific thought, phenomena are interpreted in terms of cause-and-effect relationships. One event is taken to be the cause of another, which is its consequence. Yet this representation greatly simplifies reality. In most situations, a phenomenon does not result from a single cause, but from a set of simultaneous conditions: physical, biological, environmental, and historical factors that converge to produce a certain state of the world. Causality thus appears as a plurality of conditions rather than as a simple chain linking an isolated cause to a determined effect. Moreover, it is impossible to identify a precise moment at which the cause "becomes" the effect: what we call cause and what we call effect are merely two ways of partitioning a continuous process. What we call causality therefore corresponds to the way the brain organizes and interprets these relationships in order to understand and anticipate phenomena.

## CONCLUSION

The illusions, linked to the myth of consciousness, appear in two domains: the cerebral domain and the relativistic domain. The first domain concerns the functioning of the brain, which constructs the self, its agency, and its free will. This brain-self mentally processes external information—sensations and perceptions. It also processes internal informational contents: mental representations, conceptions, coherence, and destiny. It is always this brain-self that situates the self in the universe, between spatiality, temporality, movement, and energy. And in more specialized domains: fundamental interactions and the laws of Nature.

The second domain concerns the way we represent the very structure of the world. Everyday experience gives us the impression of living in an ordinary universe: a three-dimensional space in which things move, where events appear and then disappear, where the present follows the past and opens onto a still indeterminate future. Yet the relativistic description of the universe leads to a very different picture.

The universe no longer appears as a stage where things happen successively, but as a four-dimensional structure of spacetime, in which all events are distributed. Within this structure extend the worldlines of all objects and all physical processes: particles, fields, atoms, rocks, plants, animals, humans, planets, stars, and galaxies. Each entity corresponds to a complete trajectory inscribed in the fabric of spacetime, rather than to an object that would exist only in the present moment. These worldlines extend from the aftermath of the Big Bang to one of the hypothetical ends of the universe.

The relativistic illusion thus consists in believing oneself immersed in a world where time flows and where things happen, whereas the physical description suggests a completely different reality in which past, present, and future all equally exist within the block universe.

A final illusion reinforces this ordinary representation of the world: the one produced by the entropy gradient of our universe originating in the Big Bang. The increase in entropy introduces an asymmetry between past and future states, allowing the formation of traces, memories, and irreversible processes. This asymmetry gives the impression of a flowing time and unfolding events, whereas it simply corresponds to certain statistical properties of the universe. It is this entropic asymmetry (low entropy at the beginning of the universe and increasing entropy since then) that explains consciousness and all these illusions[184].

Between the two domains of illusion, a hierarchy thus emerges. The relativistic illusion is the container of the cerebral illusions. It is because we are convinced that we live in a three-dimensional universe, with time flowing, that cerebral illusions develop, which finely construct a self in action, with its free will, and so on. Escaping cerebral illusions is barely accessible through the process of Buddhist meditation. Escaping the relativistic illusion then requires significant scientific knowledge (the theory of relativity) and a good dose of imagination in order to handle metaphors, evocative images, to dialogue with “demons” and “demonesses,” to visualize…

Escaping these illusions ultimately leads to an even deeper questioning: that of anthropocentrism. As long as we interpret the world from the standpoint of the self, its perceptions, its intentions,

[184] Carroll, 2022b.

and its narratives, the human being remains the implicit center of reality. But when cerebral illusions and the relativistic illusion begin to dissipate, this centrality loses its self-evidence. The human being then appears as a particular form among others within the immense structure of the universe. The next and final part of this work will be devoted to this major consequence: the end of anthropocentrism and the attempt to think the cosmos without taking it to be a world made to our measure.

Part Seven

# THE END OF ANTHROPOCENTRISM

# 1. The anthropic illusion

A set of illusions conceals from us fundamental reality, its vacuity, and instead presents a world of objective, existential, and shimmering phantasmagorias. We perceive things and beings as endowed with an existence of their own, in themselves, independent of one another. Admittedly, we sometimes sense, like a vague impression in the background, the dependence of things and beings, but this impression remains tenuous, barely sketched, like a thin mist that immediately dissipates. We thus forget that things and beings appear only in dependence on one another, according to what Buddhism calls "dependent co-arising."

In Buddhist thought, dependent co-arising and vacuity belong to the same register: that of reality as it is. Both describe the real structure of phenomena. Dependent co-arising expresses the fact that everything appears in dependence on causes and conditions; vacuity expresses that, for that very reason, nothing possesses an existence of its own. The illusion lies elsewhere: it consists precisely in believing that things exist in themselves, autonomously, separate from one another. It is this spontaneous reification of the world that Buddhist thought seeks to dispel. In other words, the illusion is the belief in substantial entities; the understanding of dependent co-arising and vacuity, by contrast, belongs to a correct vision of reality.

In the short list of our illusions, we have seen that of conceptions. The brain categorizes, distinguishes, names, classifies, and applies labels to things and beings. The mind can then manipulate these concepts, combine them, extend them, appropriate them, reject them, or ignore them depending on the circumstances. In the street, the gaze appropriates a handsome man, a beautiful woman, a magnificent car; one may react nervously upon encountering a person of a different origin, a dog, because one does not like them, or the delivery van blocking the way; one will pass by the homeless person on the sidewalk, lying on his cardboard, with indifference. Conceptions thus give the impression that objects and beings are naturally divided into countless implicit categories and that they possess, in themselves, meanings.

A new word may usefully be introduced here: indexation. The term belongs to information theory. Indexation is information about

information. For example, you have a library of about a hundred books. To find your way around, you open a spreadsheet and create an index. You index your books by classifying them by genre, year of publication, authors, publishers, number of pages, and so on. All this indexing information refers to another kind of information: the books themselves, both material objects and carriers of text, hence of information. Information about information.

Our brain operates through numerous indexations that clothe reality and translate it into "our reality." Try looking at a text written in an alphabet you can read, or better yet in your own language. Simply try to look at it without reading it. You will find that it is practically impossible. When I was a child, during long car journeys filled with boredom, I amused myself by trying to look at road signs or billboards without reading them. Faced with the impossibility of the task, I thus began to discover the automatic and compelling nature of brain functioning. Our brain constantly, immediately, and automatically indexes the signs it perceives and transforms them into words, into meanings. Our brain "reads," despite us—try it!

Take a bowl. Any bowl: your bowl for morning café au lait or a Tibetan singing bowl. It is a simple and tangible object. Yet this bowl will acquire meaning, will become individualized in a way, will become an apparently independent object because it is designated through an indexation as "bowl." On the one hand, as a generic concept, "bowl," which refers to all bowls and is distinguished from plates or glasses; on the other hand, as a particular object, "that bowl," at this moment, or "a Tibetan bowl," or "my friend's bowl," or "my bowl," the one that is here, right now.

We are going to apply various indexations to this bowl, to attach intellectual labels to it—even if this is sometimes done quite literally, for example in a large family where each child has his "my bowl," clearly marked to avoid conflicts. Once indexed, we will have the illusion that this bowl occupies a place in space, at a certain distance, with a three-dimensionality, over a duration. Added to this are elements of shape, texture, and color. And if I use the utensil, elements related to touch, sound, and even smell or taste may appear. All these characteristics of the bowl are indexations that bring it into focus. Each of them constitutes information about the basic information that is the bowl itself, prior to any indexation. But how can we truly see this "bowl in itself"?

Imagine yourself as a member of a very primitive tribe living in a desert, as in the film *The Gods Must Be Crazy*[185]. Replace the Coca-Cola bottle thrown from an airplane with a Tibetan bowl lost by an eponymous lama who happened to pass by. In your tribe, no one has ever made or used such an object. It first appears as something incomprehensible, that is, without any indexation—except perhaps the one that would consist in saying "unknown and incomprehensible object." But this will not last. The Bushmen are human beings like any other. Their brain will immediately get to work: observing, comparing, manipulating, testing. Gradually, indexations will appear, possible uses, interpretations. The object will enter the network of concepts, receive names, functions, meanings. Quickly, from "unknown bowl," this bowl will become a "this is my bowl," a "I found it," a "I saw it first," or "this is the chief's bowl," "this is the gods' bowl," "this is a cursed bowl," and so on. A moment before, it was nothing more than a thing without status; it now becomes an object of the world, caught in the system of human indexations.

Yet, at its base, this bowl does not exist as an independent entity. If one examines its temporality, one finds that the matter of which it is composed—the metals that constitute it—was synthesized in a star before entering into the composition of the crust of our so-called rocky planet. These metals were then extracted, worked, and shaped by human ingenuity to produce this particular object, endowed with this circular and concave form that we call a bowl.

Later on, after thousands, millions, or billions of years, these same metals may disintegrate, the atoms disperse, or even be transmuted within a star. The bowl will then have completely disappeared. Even at this very moment, from instant to instant, this bowl depends on Earth's gravity, which anchors it to the ground. It also depends on atmospheric conditions that may alter its surface state. If it were propelled into the vacuum of space, its fate would be linked to various cosmic radiations which, over millions of years, would eventually disintegrate it. In short, this bowl depends on everything: on everything that has constituted it and on everything that will make it disappear. One can thus say that it does not exist in the sense of an autonomous entity.

[185] Directed by Jamie Uys, 1980.

**Figure 54** This bowl does not exist, in itself, as an independent entity. It is nothing more than a mental construction based on concepts, names, functions, meanings…

It is only one element among others in the magma of information of the universe. This is what Buddhism designates as dependent co-arising: a phenomenon that appears only in dependence on multiple causes and conditions (nothing arises by itself; everything appears because other phenomena make it possible), and which, for that very reason, is entirely interdependent (no phenomenon possesses autonomous existence; each exists only in relation to all the others).

We are dealing here with a thought experiment. Starting from an extremely simple object—a Tibetan bowl—we have applied a whole series of indexations: a name, a function, a form, a place in space, a duration in time, sensory qualities. Little by little, this object has appeared to us as a stable and independent thing. Yet, by examining this bowl a little more closely, we have seen that it never exists by itself. Its matter comes from the stars, its existence depends on multiple physical, chemical, and environmental conditions, and its becoming is already inscribed in the processes that will eventually transform and dissolve it. The bowl we thought simple and autonomous thus turns out to be a conditioned and interdependent phenomenon: conditioned because it appears and disappears from a multitude of causes and conditions, interdependent because it exists only within the network of relations that constitute it.

We will now pursue exactly the same thought experiment, but this time no longer with a bowl—a simple object of the world—but with the human being himself. Once again, our mind begins by applying indexations: a name, an identity, a personal history, a profession, a nationality, a character, a "self." All of this gives the impression of a separate individual, endowed with an existence of his own. Yet, if we examine this human being with the same attention we gave to the bowl, the same structure appears. His body comes from the matter of the stars; his life depends on air, water, food, the Earth's ecosystem, and the biological and cultural history of the species. Even his thoughts, emotions, and decisions emerge from an extremely complex set of biological, neurological, social, and historical conditions. The human being we believed to be autonomous thus reveals himself, too, to be a conditioned and interdependent phenomenon, a particular configuration within the immense network of relations that make up the universe.

This illusion rests on several cognitive mechanisms. First, our brain indexes the world from our own perceptual and biological

point of view: we perceive the universe from Earth, from our species, from our sensory system. Next, we tend to project intentions, purposes, or meanings onto natural structures. Finally, human consciousness, capable of reflecting upon itself and upon the cosmos, easily gives us the impression of being something exceptional, even essential, within the economy of the universe.

From a scientific point of view, however, nothing allows us to assert that the universe was made for man or that it converges toward him. The human being appears rather as an extremely late and contingent biological configuration in cosmic history, emerging on a small planet around an ordinary star, in a galaxy among hundreds of billions. The anthropic illusion consists precisely in forgetting this contingency and in reinterpreting the cosmos from our own presence, as if it constituted the center or the finality of the whole.

The question then appears in a particular form in contemporary cosmology with what is called the anthropic principle. In its weak version, it is a simple methodological remark: we observe a universe compatible with our existence because, if that were not the case, we would not be here to observe it. In other words, among the immense variety of possible states of the universe, we can only observe those that allow the emergence of observers like us. The weak anthropic principle says nothing about intention or purpose; it merely recalls an unavoidable observational bias: seeing the universe through the "lenses" of our own existence.

The strong version of the anthropic principle introduces a much more loaded idea. It asserts, in various forms, that the universe must possess the properties necessary to produce life and consciousness, as if the emergence of observers were somehow part of its deep structure, of a cosmic plan. In some interpretations, the universe would almost seem oriented toward the emergence of consciousness, thereby subtly reintroducing a form of cosmic purpose: "human consciousness is the destiny of the universe."

It is precisely here that a possible way out of the anthropic illusion comes into play. The weak anthropic principle can be understood as a simple selection effect: we observe a universe compatible with our existence because only such universes can be observed by beings like us. But the strong anthropic principle, by contrast, reinstates the human being at the center of the cosmic picture. It suggests,

explicitly or implicitly, that the universe has the vocation of producing observers.

Escaping the anthropic illusion thus consists in reversing this perspective. The universe is not a device designed to produce man; the human being is an extremely particular and late configuration within cosmic evolution. Like the Tibetan bowl in our thought experiment, the human being is also a conditioned and interdependent phenomenon, arising within the network of causes and conditions that run through the history of the universe. Human consciousness is not the goal of the cosmos; it is one of its possible episodes. In this sense, the human being is not the center of the universe, but a local and transient form within the immense dynamic of dependent co-arising.

We can summarize this thought experiment by drawing a parallel between the simplest object and the human being himself: in both cases, indexations produce the illusion of autonomous entities, whereas in reality they are conditioned and interdependent phenomena.

| | **Tibetan bowl** | **Human being** |
|---|---|---|
| **Illusions by indexation** | An object named "bowl," endowed with a form, a use, a place in space and in time. It appears to be a stable and independent thing. | An individual with a name, endowed with an identity, a character, and a personal history. He appears to be an autonomous and separate "self." |
| **Dependent co-arising** | A temporary assembly of metals forged in stars, shaped by human activity, and dependent on multiple physical and environmental conditions. | A biological and mental configuration arising from cosmic and terrestrial evolution, dependent on air, food, society, culture, and countless causes and conditions. |

This table shows that the difference between a simple object—a Tibetan bowl—and the human being is far less profound than our intuition suggests. In both cases, the mind applies indexations: names, categories, functions, identities. These indexations give the impression that there exist distinct, stable things endowed with an

existence of their own. The Tibetan bowl becomes an autonomous object; the human being becomes a "self." But as soon as we move beyond the level of labels to examine the real conditions of existence, the same structure appears. The Tibetan bowl, like the human being, is nothing more than a temporary configuration arising from an immense network of causes and conditions. Both exist only in a relational, dependent, and transient manner. The difference between them is therefore not a difference of nature, but only of complexity. Beneath the Mona Lisa, René Magritte could have written, "This is a Tibetan bowl."

Let us go further still. Let us situate the Tibetan bowl and the human being within the block universe. Dependent co-arising—this interdependence in which everything appears in dependence on causes and conditions, and in which vacuity deprives everything of inherent existence—is coupled with the intertwining of worldlines, those of the Tibetan bowl and of the human being. Imagine the twisting braid of the bowl and the human when the latter takes it, places it before his ankles, makes it sing by turning the mallet along its rim… And then place all of this, this four-dimensional braid, within the omniversal fractal. Here ends the anthropic illusion.

## 2. The decentered human

At times, the poet knows how to become a cosmologist and a philosopher—and to surpass them, by adding beauty:

> "Man, do you imagine yourself, by chance,
> To be anything other than a point in blind nature?
> You, man—ash and flesh—do you persuade yourself
> That the shadow of a function has clothed you?
> What right do you think you have to seek, to pursue,
> To grasp what may exist, endure, live,
> To seize, to know, to understand—you who are
> But a larva, and who die as soon as you are born?
> I marvel at your unheard-of nothingness, if it supposes
> That it is counted for something by the infinite!"[186]

In this fragment of the poem "Dieu," Victor Hugo radically overturns the human perspective: man, who believes himself to be the center, the knowing subject and the master of meaning, is reduced to an infinitesimal position within the immensity of nature. "A point in blind nature" strips the universe of any intention or purpose oriented toward man. The human being, "ash and flesh," is nothing more than a fragile and transient episode, a "larva" with a brief life, within a cosmic process that surpasses him on all sides. The poet then expresses, without any ambiguity, the anthropic illusion: "I marvel at your unheard-of nothingness, if it supposes – That it is counted for something by the infinite!" Man believes himself to be counted in the economy of the universe, as if the infinite had to grant him a particular place. Man ceases to be the center and becomes an insignificant configuration, among others, within the cosmic immensity.

Cosmological parochialism, or the temptation of the center. Ever since man has raised his eyes to the sky, he has seen himself

[186] Victor Hugo, in *La Légende des siècles*, "Dieu," IX.

everywhere in the middle. This reflex of anthropocentrism—the parish mindset applied to the universe—runs through the entire history of thought. It is the tendency to reduce the immense to the measure of the human, to believe that the cosmos is organized around our point of observation, our planet, our galaxy, or even our favorite theory.

In Antiquity, the Earth stood immobile at the center of the spheres. When Nicolaus Copernicus moved the Sun to the center, it was thought that geocentrism had been overcome—but only to invent a new heliocentrism: the same circle, shifted by one step. And when modern astronomy revealed that the Sun is only one star among billions, human pride took refuge in the Milky Way, presumed unique, before discovering that it was only one galaxy among billions of others. Each revolution in knowledge decenters us, but our imagination immediately recenters us. We change centers as we change clothes; the need to inhabit the middle of the world seems impossible to uproot.

Even contemporary science, though armed with telescopes and equations, does not escape this subtle bias: most cosmological models are based on what we can observe from within our horizon bubble. We take the local map for the global territory. The Big Bang becomes a universal event, whereas it might be only a regional history; our observable universe, a mere fragment of a larger structure. Many researchers, even those open to quantum plurality, still reject the idea of a multiverse as an offense to scientific parsimony—as if reality, for the sake of elegance, had to be limited to our field of view.

This parochialism is not expressed only in science, but also in language: we speak of the "top" and the "bottom" of the universe, of the galactic "center," of the "limits" of the cosmos, as if these reference points still had meaning in the absence of any absolute. It is more reassuring to draw boundaries than to admit infinity. We prefer a finite cosmos, inhabitable by reason, to a boundless universe in which all meaning dissolves.

Yet each stage of cosmology has consisted in pushing back these mental boundaries. From the sky of the gods to Einstein's spacetime, from Milky Way of William Herschel to the galaxies of Edwin Hubble, from a single universe to the multiverses of Max Tegmark, the history of ideas is that of a continuous decentering. And yet we

remain Earthbound even in our equations. Even our boldest hypotheses retain the trace of this nostalgia for the center: the desire that reality conform to the scale of our mind (and of our brain, one might add).

Cosmological parochialism is, in sum, our last metaphysical refuge. As long as we insist on having only one universe, we are still talking about ourselves: about our need for a familiar, closed, measurable world. We are still the natives of the cosmos. But if it is truly infinite, if multiverses are nested infinitely within the fractal structure of the omniverse, then settling for a single multiverse might be… somewhat small-minded. The conclusion thus imposes itself: man is no longer at the center—and since the universe has no center, man disappears altogether.

To understand this more clearly, let us strike some sparks. The spark as a unit of human forms. If we restrict ourselves to humanity in the strict sense—that of *Homo sapiens*—its appearance dates back to about 300,000 years. On the scale of cosmic history, this duration is almost imperceptible. The universe is about 13.8 billion years old, and the Earth itself more than 4.5 billion years old. Humanity thus emerges extremely late in the evolution of the cosmos. Even if one were optimistic and generous in imagining a total duration of humanity of one million years, this would still remain negligible compared to the billions of years of cosmic history. Such a humanity would then appear as a very brief phenomenon, a fleeting biological and cultural configuration within a vastly longer cosmic process. A spark.

Yet the history of the universe is far from over. Stars will continue to form for roughly another 100 trillion years. During this entire period, new planets may appear, and some could, in principle, host intelligent forms of life. If humanities comparable to ours emerge here and there, and if each lasts only about one million years, their existence would still remain extremely brief relative to the total duration of this cosmic era. Each humanity would then represent a very short appearance in the immense unfolding of cosmic time. Sparks.

In a block universe, one could then imagine a multitude of very brief sparks appearing here and there in cosmic history, each lasting about one million years, scattered across a temporal interval that begins around 14 billion years after the Big Bang and could extend to

roughly 100 trillion years. Beyond that, star formation will gradually cease, and conditions favorable to life will become increasingly rare. The universe will then enter a very long dark phase dominated by stellar remnants and black holes.

If we widen the perspective further and move beyond the scale of a single universe to consider a multiverse, the picture changes in scale, but the structure remains the same. In an inflationary multiverse, each universe has its own cosmic history, its stars, its planets, and possibly its forms of life. Possible humanities still appear as extremely brief phenomena: tiny sparks of consciousness within the immense cosmic duration proper to each universe. But these sparks are no longer scattered within a single universe; they are spread across a multitude of different universes, many of which are not even conducive to the emergence of life or consciousness. Only a fraction of them bring together the physical conditions necessary for the formation of stars, planets, and complex chemistry; and among those, an even smaller fraction may give rise, for a cosmic instant, to a humanity capable of wondering what the universe is.

If we push the reasoning further toward the idea of an ensemble of multiverses, the distribution becomes vertiginous. The spark then changes scale. It is no longer only humanities that appear briefly within the time span of a universe, but universes themselves that constitute the sparks. In an inflationary multiverse, countless universes may arise, each with its own physical laws, constants, and cosmic history. Many of them will allow neither the formation of stable atoms, nor that of stars, nor that of planets. But some universes, rarer ones, will possess the conditions necessary for the formation of stars and habitable worlds.

From this perspective, a multiverse may be imagined as a vast ensemble within which sparks of universes appear, capable perhaps, in turn, of harboring sparks of humanity. Most of these universes will remain silent, unable to produce complex structures. But a few, for a certain period of their cosmic history, may see the emergence of those brief glimmers that are conscious humanities.

At the scale of a fractal omniverse, the picture becomes even more radical. Entire multiverses appear and disappear, and among them some contain universes capable of generating stars, planets, and, very rarely, humanities. The omniverse will then be almost entirely

dark and silent, scattered here and there with sparks of universes—and, in some of those universes alone, with sparks of humanity that, for a cosmic instant, begin to reflect on the whole of which they perceive only an infinitesimal part.

At this scale, decentering becomes complete. The human being ceases to appear as the center, the goal, or the meaning of the omniverse. He becomes a local and transient configuration within the immense unfolding of the cosmos. A humanity is only a brief spark in the history of a universe; a universe capable of harboring a humanity is itself only a spark within a multiverse; and multiverses themselves may be nothing more than sparks within an even larger structure: the fractal omniverse.

At this scale, decentering is total. The human being no longer appears as the center, the goal, or the meaning of the omniverse. What was once called "the place of man in the universe" dissolves: humanity is nothing more than one phenomenon among others within the immense fabric of cosmological processes. A spark of a spark, of a spark, of a spark… humanity then appears as an ephemeral and infinitesimal glimmer, completely and definitively decentered within the fractal omniverse, marking the end of the centered human.

# 3. The human without meaning

Once the anthropic illusion has dissipated, the human being ceases to appear as the center, the purpose, or even the measure of the cosmos. In a fractal omniverse where universes and multiverses multiply and interlock at all scales, humanity is no more than a local, transient phenomenon, a particular configuration of organized matter within one universe among an infinity of others. Meaning can therefore no longer be sought in a cosmic centrality or in a privileged destiny of the species. It shifts toward a lucid understanding of our condition: an extremely improbable emergence of structures capable of knowing themselves and reflecting on the whole to which they belong. In this framework, the human being is no longer the goal of the universe, but one of its modes of reflective emergence.

This situation then opens up other questions, perhaps more radical ones. If universes, multiverses, and the fractal omniverse are not produced for man, how are we to think the place of a consciousness capable of grasping part of this structure? What does the local appearance of human beings mean—beings capable of intellectually reconstructing cosmic history, from the cosmic microwave background to galactic structures, and then imagining the existence of countless multiverses? One of the major questions thus becomes that of the relationship between material complexity and the emergence of consciousness: why do certain regions of the omniverse produce systems capable of experience and thought, while the vast majority of the fractal remains silent?

Another question concerns the actual scope of this consciousness. In a block universe, or in an ensemble of block universes, what we call experience, decision, or personal history is only a particular trajectory inscribed within the global structure of spacetime. The human being then discovers himself as a determined phenomenon, traversed by causal chains that trace back to the initial conditions of the cosmos. The question of free will, already weakened by neuroscience and physics, becomes an inquiry into the very nature of subjective experience: how can an illusion of freedom emerge from a fully determined universe?

Finally, the most vertiginous question arises: that of the very meaning of knowledge. If the fractal omniverse is potentially infinite, human intelligence can grasp only a minuscule portion of it. Yet this small region of organized matter manages to reconstruct general laws, to formulate cosmological models, and to conceive the existence of scales that radically exceed it. The human being then appears as a cognitive spark within a cosmic whole immeasurably larger than himself. The great contemporary question may no longer be "what is the place of man in the universe?", but rather: how has a fragment of the omniverse come to think itself?

These questions may be reformulated into more synthetic sub-problems. They first concern the place of consciousness in a non-anthropocentric cosmos. They then address the emergence of a cosmological intelligence within a local region of the universe. They also question the extremely uneven distribution of consciousness within the fractal omniverse. They lead us to examine the phenomenal emergence of free will in a deterministic universe. And they ultimately culminate in the question of the omniverse's local self-reflexivity.

From this point, the ultimate question arises: what meaning can still be attributed to the human being within the fractal omniverse? Two answers are possible. We may choose to preserve the idea of a meaning specific to the human, but we must then be able to define it without relying on a now-vanished cosmic centrality—a task that remains a considerable challenge. Or we may consider that the human possesses, in himself, no particular meaning, that he is only a local and transient configuration of matter, and that he must then be placed "outside meaning" within the general economy of the omniverse.

To maintain the idea of a meaning specific to the human, without being able to anchor it in a now-abandoned cosmic centrality, becomes a task that concerns several traditions of thought. It first belongs to philosophers, who have historically taken on the question of the meaning of existence when cosmological frameworks are transformed. It also concerns religious traditions, many of which are based on the idea of a creation ordered around man and must therefore reformulate their anthropology within an immensely larger and indifferent universe. It also touches, more recently, certain scientists and thinkers in contemporary cosmology, who

question the significance of the emergence of consciousness in a universe governed by impersonal physical laws. The question of the meaning of the human, once the anthropocentric illusion has dissipated, thus ceases to belong to a single domain: it becomes a transversal problem, at the intersection of cosmology, philosophy, and spiritual worldviews.

In this work, armed with a deliberately lucid line of thought, we will leave to philosophers, to religious traditions, and to scientists who wish to persist in it, the perennial question of a cosmic meaning to be attributed to humanity. The temptation to preserve a particular significance for the human within the general economy of the cosmos remains strong, but it almost always rests, explicitly or not, on the remnants of an older anthropocentrism.

For our part, we will follow another path. In the perspective of the fractal omniverse, the human being carries no intrinsic cosmic meaning. He is simply a local, transient configuration of organized matter capable of representing a portion of the structure to which it belongs. In this sense, the human is without meaning, and this entire book has sought to lay out, justify, and assume the consequences of that position.

Without meaning because we have moved beyond perceptual and symbolic cosmologies that placed the human at the center of immediately readable worlds. Without meaning because we have moved beyond theological relational cosmologies that made man the privileged interlocutor of the cosmos and of the powers that might inhabit it. Without meaning because we have moved beyond the sidereal universe, that of fixed stars surrounding the Earth like an ordered stage for human existence. Without meaning because we have moved beyond Edwin Hubble's universe and discovered an expanding cosmos in which our galaxy is only one among hundreds of billions of others. Without meaning because we have moved beyond the observable universe itself, understanding that it is only a limited portion of a larger whole beyond the cosmic horizon. Without meaning because we have moved beyond the block universe, where the time we believe we experience is only a four-dimensional structure already inscribed in the geometry of spacetime. Without meaning because we have moved beyond multiverses, which further dissolve the idea of a single world in which man might claim a privileged position. Without meaning

because we have reached the perspective of the fractal omniverse, where universes multiply and interlock without center or purpose. Without meaning because we have understood the role of the entropic gradient in the illusions of our consciousness, revealing that our sense of the flow of time, of choice, and of freedom arises from a local physical process. Without meaning, finally, because we have demonstrated the end of anthropocentrism and recognized that humanity is only a transient configuration of organized matter, appearing in a corner of the fractal omniverse and destined, like all things, to disappear.

In Buddhism as well, dependent co-arising already places the human outside of meaning: no being, no thing exists for itself or for an ultimate purpose; everything is only an interweaving of causes and conditions. This radical intuition now converges with what modern cosmology reveals. With the fractal omniverse, the universe definitively ceases to be an ordered framework centered on humanity. Universes multiply, structures unfold without center or destination, and man drifts—irremediably entangled in his worldlines. **And within this purposeless whole, the human is, indeed… without meaning.**

# 4. Looking out the window: an infinite claustrophobia

Let's imagine, for a moment, the simplest possible scene. We are in a room, at home, and we open the window. The gesture is ordinary. We pull the shutters, the air flows in, and our gaze turns outward. Depending on where we are, we see a landscape, hills, a city, or simply the sky. At night, that sky may be filled with stars. Points of light appear, silent, distant, as if suspended in a depth our eyes struggle to measure. Since the beginning, human beings have looked out through this window. Since the beginning, they have imagined what lies beyond what they see.

For millennia, this opening onto the outside was accompanied by an almost instinctive conviction: there must be something behind this cosmic landscape. An order, a center, a destination, a meaning. Perceptual and symbolic cosmologies placed the human being at the heart of the world. Theological relational cosmologies made him the privileged interlocutor of the universe and its powers. Even the sidereal universe of early astronomers retained a certain familiarity: a closed, structured sky, where stars traced regular spheres around the Earth.

Then the window opened wider.

With the Copernican revolution, the Earth left the center. With modern astronomy, the sky filled with an immense multitude of stars. In the twentieth century, Hubble's universe revealed hundreds of billions of galaxies. The observable universe itself emerged as a region bounded by a cosmological horizon. Then relativistic physics introduced the block universe, in which the time we believe we experience unfolds as a dimension of the global structure of space-time. Inflationary cosmologies opened the possibility of multiverses. Quantum mechanics, with Everett's interpretation, introduced another form of proliferation of the real, giving way to a multiplicity of coexisting worlds. And finally, contemporary cosmological reflection has brought forth the vertiginous hypothesis of an omniversal fractal: a set of universes generating and unfolding without center, without edge, without any accessible totality.

At each stage, the window widened.

But an unexpected phenomenon occurred. The more the window opened, the more the place of the human dissolved. What appeared behind the glass was not a landscape organized around us. It was a structure increasingly vast, increasingly indifferent, increasingly foreign to any human purpose.

To look through the window of the omniverse is thus to look into a cosmic fractal. A structure comparable to certain mathematical images such as the "Sapphires," where forms repeat, unfold, and branch infinitely. Where each level reveals further levels. Where each region contains other regions. Where no ultimate boundary ever appears.

We are there.

And it is precisely at this moment that a strange feeling emerges, an almost impossible oxymoron: an infinite claustrophobia. For this cosmic landscape, vast as it may be, is not an outside. It is the whole. We are not looking toward the exterior of a system. We are looking at the interior of the totality to which we belong. And this totality, by definition, has no beyond. Nothing exists behind it. Nothing envelops it. Nothing surpasses it.

The omniversal fractal has no exterior.

Within such a framework, the very idea of escape disappears. There is no exit, no breach, no traversable boundary. Everything that exists already belongs to this whole. Even imagination, even the most audacious theories of cosmology, even multiverses, remain within this structure.

We are enclosed within the whole.

This is the claustrophobic dimension of the situation. Not confinement within a narrow space, but confinement within the absolute totality. The fact that nothing can exist outside what exists. And yet, this confinement has no limit. The omniversal fractal is not a closed space. It is not a cosmic sphere. It has no edge. It unfolds indefinitely. Universes multiply within it, structures repeat within it, scales extend without end.

This is the infinite dimension of the situation.

But this emergence does not in any way modify the general structure of the cosmos.

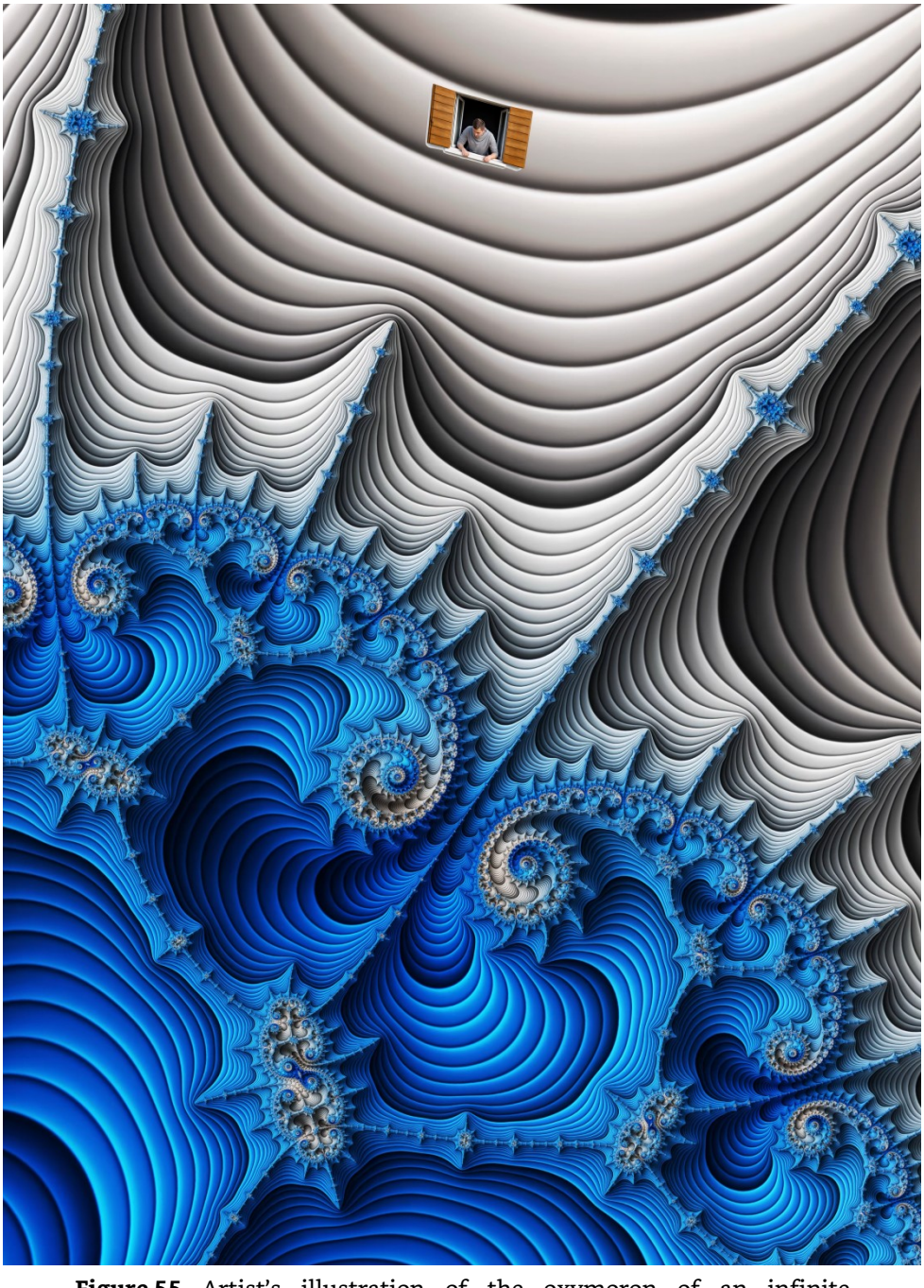

**Figure 55** Artist's illustration of the oxymoron of an infinite claustrophobia. An open window onto the omniversal fractal: one is enclosed within it, yet it is infinite.

Human consciousness is not the goal of the omniverse. It is not its purpose. It is not even an essential component of it. It is simply one of the possible effects of certain configurations of matter in certain regions of the fractal.

A local phenomenon.

Modern cosmology, together with the sciences of the brain and the analysis of the entropic gradient, moreover shows that subjective experience itself rests on functional illusions. The flow of time, the sense of identity, the impression of free will all emerge from determined physical processes. In the block universe, our worldlines are already inscribed in the geometry of space-time. We slide along these lines, convinced that we are moving forward, convinced that we are choosing, while we are simply traversing a structure already given.

Thus closes the entire set of anthropic illusions.

Humanity occupies no privileged place in space. It occupies no privileged place in time. It occupies no privileged place in the global structure of reality.

In the omniversal fractal, the human is without meaning.

This conclusion may seem harsh, but it follows logically from the path we have taken. As human cosmologies have expanded their horizon, they have progressively dissolved the idea of a central place for humankind. Each cosmological revolution has pushed our species further toward the conceptual periphery of reality.

The omniversal fractal is simply the culmination of this movement.

It leaves no room for any residual anthropocentrism. It preserves no trace of a universe designed to accommodate us. It offers no cosmic narrative in which humanity would represent a necessary stage or an achievement.

The human is only a local fluctuation in the immense unfolding of matter and energy.

And even this formulation remains too generous. For what we call “humanity” is itself only an extremely brief instant in cosmic history. Barely a few hundred thousand years in a universe more than thirteen billion years old. A fragile, transient phenomenon, dependent on a multitude of precise physical and biological conditions.

A spark.

In the omniversal fractal, countless sparks may appear elsewhere, in other forms, in other universes, according to other physical histories. But even if such sparks exist, they change nothing about the fundamental situation.

The cosmos does not need consciousness in order to exist.

And consciousness does not need cosmic meaning in order to arise.

To look through the window of the omniverse is therefore to look at a landscape that was not waiting for us. A landscape that does not recognize us. A landscape that promises us nothing.

We are simply there, at a particular location within the fractal.

And perhaps this is, paradoxically, the most radical form of cosmic lucidity. Not to discover a hidden meaning behind the universe, but to accept that no meaning is inscribed in it for us.

The window is open.

Before us, the infinite.

**And within this infinite, which has no outside, not only is the human without meaning, insignificant, but it there displays its most formidable nothingness.**

# Epilogue

A book that was written like a novel, with the same surprises and the same moments of astonishment as it unfolded. New ideas would emerge, chapters would appear, sections would be added, unforeseen in the initial plan, as if the work were discovering itself while being constructed, gradually revealing what felt like a genuine inspiration.

I was both happy and surprised to discover, little by little, how long this book had been present in my own life. A book in which I am "at home," within my own thinking, since childhood. From my first cosmological school essay in primary school, through some of my youthful writings dating back to 1981[187], when I was twenty-eight years old, and later texts[188] in which science and philosophy were already intertwined, all these writings foreshadowed the work to come, the first sketches of what would become "Omnivers."

This book comes even closer to a novel if we consider that it pursues a quest, with its hero—the human being, you, me, all of us—over 300,000 years of *Homo sapiens*. The story sets out to discover the Universe—ours first, its properties—then the multiverses, and finally the Omniverse, presented as the ultimate horizon of this long search for knowledge and understanding. The omniversal fractal then appears as the culmination of this journey. Why organize an infinite number of universes, distributed across an infinite number of multiverses, according to a fractal structure? That is the second quest, the secondary plot: to discover how two necessities—repeating the same and multiplying the possible—can be brought together. Only a somewhat particular fractal seems capable of satisfying both requirements. It remains to be discovered and calculated, which is no longer within my domain.

The conclusions of this work may seem harsh to some readers, and the consequences implied by a universe embedded within an omniversal fractal are no less so. Throughout the dozens of works consulted in preparing Omnivers, all written by eminent scientists—

[187] Loonis, 2021.

[188] Loonis, 2022, 2023.

physicists, mathematicians, cosmologists—an odd restraint becomes apparent: so much resistance to following reasoning through to its end, so many stubborn refusals to draw the most obvious conclusions. There is no free will, there is no self, there is no agent. How often do we find beautiful descriptions of the four-dimensional Einsteinian universe, where all events—present, past, and future—exist in the same way, without ever daring to give it its true name: the block universe. A name almost cursed, too strong, too explicit, which immediately leads to the abandonment of free will—something the authors seek at all costs to avoid. In many of these authors, one senses a form of dissociation between their personal convictions, which they strive to preserve, and the implications of the scientific data. This work on the omniversal fractal seeks no such compromise: it moves forward without concession, removing in turn the self, consciousness, and free will from the global stage, relegating them to the backstage of illusions.

I would now like to address more specifically those readers who might feel troubled by so many renunciations: the human dethroned from the center of the universe, the human reduced to nothingness. What, then, are we to do? What are we to make of our lives? My answer is first that this nothingness is not devoid of interest, especially when it applies to everything. The omniversal fractal, this infinite claustrophobia glimpsed through the window of our lives, does not lead us to overturn our existence. It rather invites us to continue living as we already do, but with greater detachment, and perhaps with the satisfaction of having profoundly altered our view of the cosmos.

And then remains the question of questions: the *G* question. What about God in all this? The temptation is great to echo the reply that Laplace gave to Napoleon when the latter expressed surprise at never seeing the Creator mentioned in his great work on the system of the world: “Sire, I had no need of that hypothesis.” Once the omniversal fractal is understood—a totality to which nothing can be added, since it is the whole—each person is free to situate God as they see fit. One may place Him inside or outside, above or below, in a transcendence (which is no doubt the most reasonable option), or elsewhere still. I can be of no help in this matter, which has not been mine for a long time. The omniversal fractal does not provide for divinity, but neither does it forbid it.

Since the prologue, the reader knows that the author is not "strong with equations." These should therefore be seen (1) as a touch of humor, without any mockery, simply as a way of putting things back into perspective and relativizing them, implicitly echoing the intuitions of certain mystics or thinkers:

$$\begin{aligned} & G \cong \infty \\ & \infty \cong 0 \\ & \Rightarrow G \cong 0 \end{aligned} \qquad (1)$$

The omniversal fractal proceeds otherwise. Our lives are so brief that they are but a spark within the Omniverse. We are here by chance, without motive, without any particular place, except for this slender point of anchorage that is our planet around its Sun, within its galaxy. We are nothing, and yet alive, conscious. What, then, do we lack? Perhaps the courage to face this truth of our nothingness and to turn it into a challenge: that of confronting this Omniverse, immeasurably larger than ourselves, and drawing from it a form of wisdom grounded in humility. As an ultimate renunciation, no longer seeking to grasp our place within the Omniverse.

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My thanks first go to the dozens of scientists who contributed to my education through their books and articles. Their guidance, over the years, day after day, through their texts, concepts, and theories, provided the intellectual raw material upon which this essay was built.

Among these scientists, I would like to thank more particularly Aurélien Barrau, who opened the way for me toward the multiplicity of universes. Sean Carroll, for his abundant explanations concerning the effects of increasing entropy. Jacques Demaret, who proved highly pedagogical in his presentation of contemporary cosmological theories and, together with Dominique Lambert, enabled me to question the centrality of the human in the universe and to deepen everything there is to know about the anthropic principle. Thanks again to Brian Greene, whose books must all be in my library, and who has proven an inexhaustible source of highly up-to-date knowledge on the arcana of the cosmos, parallel universes, and the place of the human being. Thanks to Alan Guth for his brilliant idea of inflation. My warmest thanks to Sabine Hossenfelder, who conducts her research at the Institute for Advanced Studies in Frankfurt, for her incisive book revealing the misdirections of modern physics, blinded by the beauty of its equations. Thanks also to Marc Lachièze-Rey, from whom I learned so much about time, and to Thibault Lepeltier, who boldly questions the very existence of the universe—a healthy inquiry. My thanks as well to Jean-Pierre Luminet who, along with Lachièze-Rey, set me on the path toward questions of infinity and multiverses. I do not forget Robert Sapolsky, whose two works I had the great honor to translate, and whom I warmly thank for his demystifying ideas and demonstrations concerning human behavior and its determinism. Finally, my deep thanks to Max Tegmark, a leading author on the question

of multiverses, and whose foundational encounter proved particularly inspiring for me.

Their books, each in their own way, explore the major questions of contemporary cosmology and remain essential for acquiring a certain level of expertise. The reader will find their complete references in the bibliography. Without their work, their scientific rigor, and their remarkable ability to make the most vertiginous ideas of modern physics accessible, this book simply could not have been written. For me, as for so many readers, they have been guides in the exploration of this cosmos whose structure and meaning we modestly attempt to understand.

I would also like to express my gratitude and pay tribute to several authors now deceased, whose books have profoundly nourished my reflection. To Auguste Blanqui and David Lewis, for shedding light on what seems to me to be the two generative foundations of the universe. The first, while imprisoned, sketched as early as the nineteenth century the vertiginous idea of a cosmic repetition of the same to fill an infinite universe. The second, a contemporary thinker, with his theory of the plurality of worlds, opened a radical philosophical perspective—modality—in which all possibilities find realization somewhere. These two intuitions, coming from very different intellectual horizons, helped structure the reflection that runs through this book.

I also owe much to René Descartes. For the *Discourse on the Method* was the first philosophical text I encountered at the age of fourteen, in secondary school. I still remember the scene: the librarian seeing me rummaging through the wooden cupboard reserved for final-year students, with a frowning expression at what she considered premature curiosity—"But what grade are you in?!" Yet this hard reading was, for me, a true gateway into philosophical thought.

A profound thank you to Albert Einstein, as well as Leopold Infeld, whose works on relativity and on the evolution of ideas in physics played a decisive role. Their

way of presenting the deepest concepts of modern physics, with remarkable pedagogical clarity, helped make accessible the transformation in our vision of the world introduced by relativity.

Finally, I would like to mention Chögyam Trungpa, a Tibetan lama exiled to the United States following the Chinese invasion and persecutions, also now deceased. Reading *Cutting Through Spiritual Materialism*, at the age of twenty-two, was a true existential turning point for me. This book, which I reread at the time—surely more than twenty times—profoundly shaped my understanding of reality and the illusions that conceal it. It remains for me a central reference in metaphysics.

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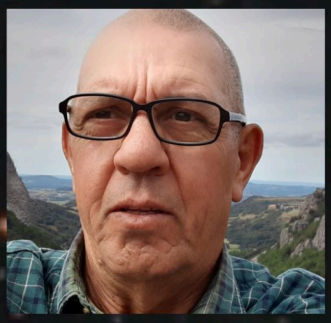

Éric Loonis is a clinical psychologist. In this book, he has ventured into the field of cosmology.

This work deals with universes. How was the universe first interpreted before it could be measured? What are the various conceptions of the universe in terms of size and geometry? Is there only one universe? Can we envision a multiverse? Multiverses? An omniverse? How can entropy explain consciousness and free will, and define a universe of illusions? How does a model of an omniversal fractal call into question the centrality of the human being, and even its very existence?

“For us convinced physicists, the distinction between past, present, and future is only an illusion, however tenacious it may be.” A. Einstein

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